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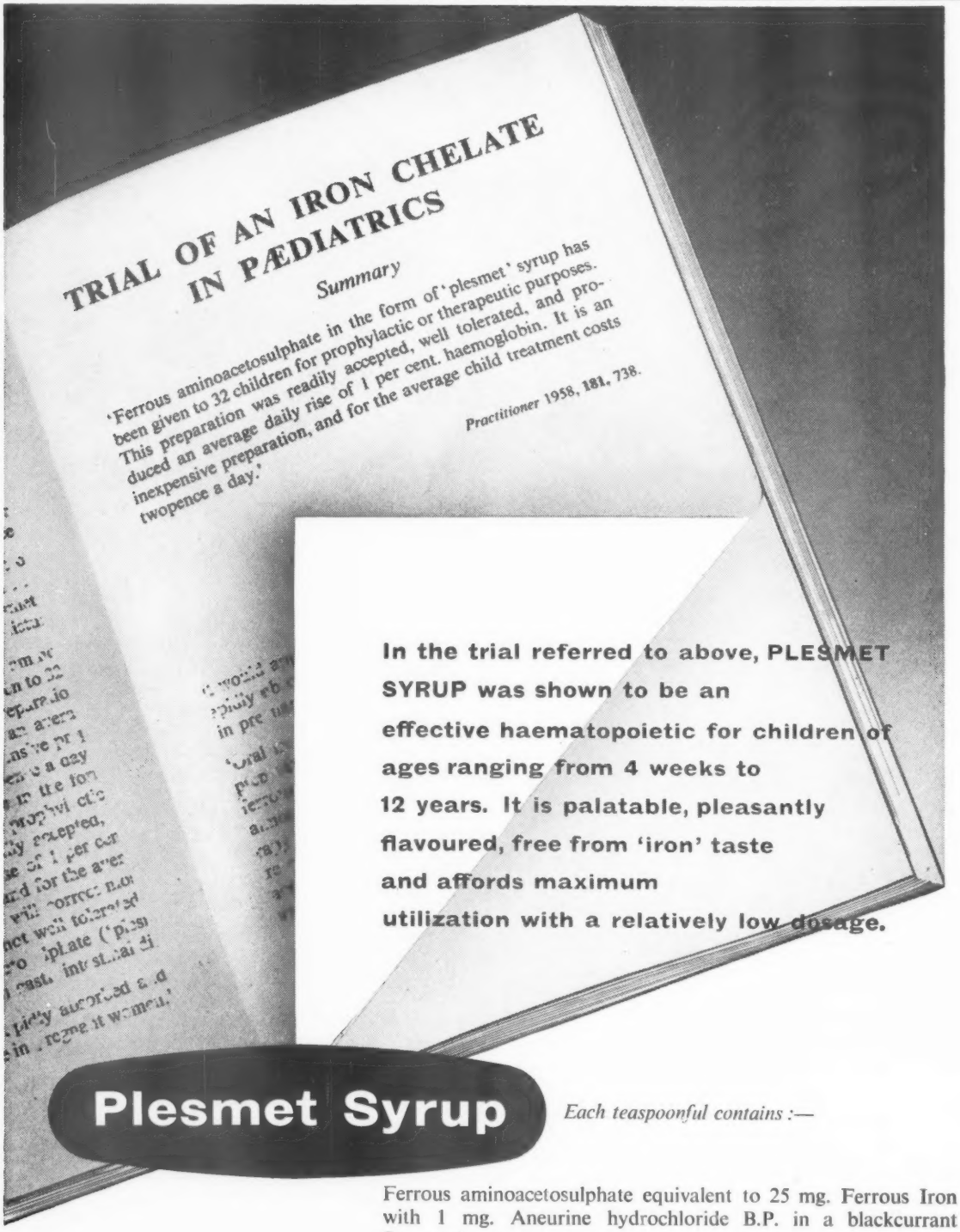
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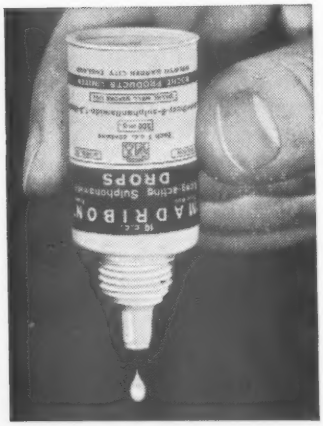

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ABDOMINAL TUMOURS IN INFANTS AND CHILDREN*

BY

C. EVERETT KOOP

From the Surgical Clinic of the Children's Hospital of Philadelphia and the Harrison Department of Surgical Research, University of Pennsylvania School of Medicine

If abdominal tumours in children were symptomatic more often than they are, diagnosis would be simple and indications for management clear. However, abdominal tumours are usually silent. Frequently they are discovered accidentally. They may well be diagnosed by chance in the systematic work-up for apparently unrelated symptoms, as, for example, in a child with a fever of unknown origin who has dullness to percussion at his left base on physical examination and in whom a chest film reveals not pneumonia but a retroperitoneal tumour.

When one speaks about abdominal tumours in children two major tumours come to mind, the embryoma of the kidney or Wilms' tumour and the neuroblastoma. These two tumours are thought of almost to the exclusion of others and perhaps rightly so. They are not only the most usual and the most dangerous to life, but are also amenable to treatment, if happily the diagnosis is made early.

Long experience with these killers of children leads one to a philosophy of tumour management. In America, at least, cancer is the No. 2 killer of children, exceeded only by accidents. Probably the same is more or less true in Britain although you do not seem to lead the frantic lives that we do and perhaps cancer is even more important as a cause of paediatric death than are accidents.

It is our firm belief that abdominal tumours present an urgency, if not an emergency situation in management. Several valid reasons might be cited in support of this belief but, for the sake of a teaching point, the naive explanation that we give is that in every tumour, such as Wilms', there is a day when metastases take place. Before this day extirpation of the primary tumour should result in a complete cure. After this day extirpation of the tumour has no effect on mortality and in all likelihood even the addition of X-ray therapy and chemotherapy to the surgeon's armamentarium probably alters the prognosis but little.

Another keystone in the management of abdominal tumours lies in ordering minimal investigations, not only because more are unnecessary, but also because the longer a child lies about the wards of the hospital, the more opportunity he has for his abdomen to be palpated by enthusiastic members of the house staff and by medical students.

The third point in our philosophical management of tumours is minimal trauma by palpation, whether this be pre-operatively or at the operating table. We attempt ligation of the blood supply to the tumour before handling it, if at all possible. This philosophy leads us to place an adhesive sign on the abdominal skin which says, 'Do not palpate this abdomen' as soon as we have made the diagnosis of an intra-abdominal mass, and commonly leads us to wide incisions of the thoraco-abdominal variety in order to approach an intra-abdominal or retroperitoneal mass without undue manipulation.

The differential diagnosis of intra-abdominal tumours is certainly important, even though the tumour must come out, because of differences in the life history of these two major malignant lesions, the Wilms' tumour and the neuroblastoma, and operative management dictated by these differences. The Wilms' tumour has a capsule and, if this is ruptured spontaneously or during the operative procedure, the prognosis is tantamount to eventual death. The pattern of metastases is to the lung fields and seldom to the regional nodes. The mortality is high, the best results being obtained in those clinics where the aforementioned philosophy is carried out and where prompt surgery is followed by adequate irradiation.

The neuroblastoma, on the other hand, is frequently non-encapsulated; its metastatic pattern is to the bones of the extremities, to the skull and retro-orbital areas. Growth by direct extension into adjacent organs is common, and the best mortality is not necessarily reported from those clinics that treat neuroblastomas as they do Wilms' tumours by X-ray treatment immediately after surgery. This tumour apparently has a unique ability to revert from a malignant to a benign form. Although we realize that little or nothing in the way

Lecture delivered at the University of Liverpool in June, 1959.

of therapy may be associated with this course of events, our own experience leads us to believe that the best results have been in those patients who had a major surgical insult to their tumour.

The intravenous pyelogram is at all odds the key study in the differential diagnosis of these two tumours. Some of the films shown here are far superior to others insofar as visualization of the kidney is concerned. The reasons for this include not only a better dye substance being available today, but also the technique currently in use for giving the patient a carbonated beverage to drink immediately after injecting the dye intravenously in order that the carbon dioxide liberated from the beverage will fill the stomach, push the viscera out of the way, and show the dye secreted by the kidney through a large radiolucent gastric shadow of gas. Furthermore, we now reinforce the intravenous dose of dye by a second injection if there is no apparent dye secretion in the first film taken five minutes after the initial injection. Perhaps a review of some of the problems presented by patients may serve to illustrate both the commonplace and the bizarre.

Case Reports

Case 1. M.B. This 1½-year-old boy had been chronically ill for four months with weight loss, fever and diarrhoea. Physical examination revealed dullness at the right lower base of the lung field posteriorly. The liver was palpable 3 cm. below the costal margin and the spleen was enlarged. The preliminary film of his abdomen showed a huge mass in the right upper quadrant with amorphous calcification. The intravenous urogram showed a typical displacement of the right kidney by a suprarenal mass. This is the usual textbook picture of a suprarenal neuroblastoma. It is classical in the position of the tumour, the displacement of the pelvi-calicea system of the kidney and in the appearance of the calcium (Fig. 1).

Case 2. D.C. A 3½-year-old boy had a three to four-week history of intermittent fever, abdominal pain, leg pain, sore joints, weakness and weight loss. The diagnosis of rheumatic fever was considered before admission to hospital. In hospital a physical examination revealed a mass in the left upper quadrant and an intravenous urogram indicated in the five-minute film displacement of the ureter both in the anterior-posterior and oblique projections. Calcium was also seen in this lesion. It soon becomes apparent that the neuroblastoma can appear anywhere from the cervical region to the coccyx. The calcium pattern varies and is not 100% reliable. Here the tumour is not in the typical suprarenal position but is below the kidney (Fig. 2).

Case 3. E.B. A 23-month-old boy had intermittent episodes of diarrhoea for one year. More recently he had had an anaemia which had not responded to iron medication but he had not experienced fever or weight loss. On physical examination a palpable abdominal mass was found in the left flank. Intravenous urography revealed a displacement of the left ureter medially and anteriorly by a retroperitoneal mass lesion containing no calcium. This also proved to be a neuroblastoma (Fig. 3).

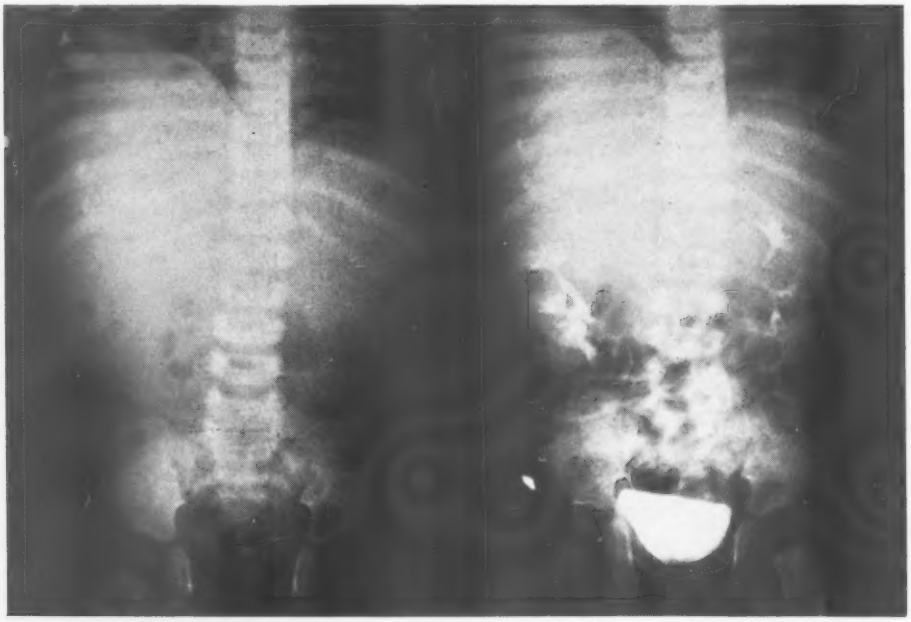

FIG. 1.—Case 1. Typical displacement of right kidney by a suprarenal neuroblastoma. Note calcific shadows.

FIG. 2.—Case 2. Neuroblastoma. Left upper quadrant mass with displacement of ureter and kidney by infrarenal mass.

FIG. 3.—Case 3. Neuroblastoma. Left ureter displaced medially and anteriorly. No calcium.

FIG. 4.—Case 4. Neuroblastoma. Mass indenting bladder and displacing ureter far laterally. Excellent demonstration of benefit derived from gas shadow in stomach produced by carbonated beverage.

Following extirpation of the tumour the child is alive and well four years post-operatively.

Case 4. S.C. A 3½-year-old girl had had poliomyelitis at the age of 4 months. One year before admission she began to complain of pain in her left leg and had numerous hospital admissions, all of which resulted in the assessment of her pain as a result of her poliomyelitis. By the time she reached the Children's Hospital of Philadelphia, the diagnosis was easy because there was a large mass not only palpable but also visible in her left lower quadrant. An intravenous pyelogram showed a mass indenting the bladder and displacing the ureter far laterally. This also proved to be neuroblastoma. The patient died six months later. The kidney is not displaced in any way in these films which show remarkably well the advantages of giving a carbonated drink in association with intravenous pyelography (Fig. 4).

Case 5. M.B. was a 5-year-old boy who entered the hospital with a four-month history of intermittent fever, pains in the joints, neck and head. At another hospital three months previously his long bones, intravenous pyelogram and skull films were all reported as being negative. By exclusion a diagnosis of Still's disease was made and he was placed on cortisone therapy. On this treatment he improved for a while but by the time of admission to the Children's Hospital of Philadelphia his pain had returned and his headaches were a primary symptom. Skull films showed evidence of increased intracranial pressure and a ventriculogram taken eight days later showed no mass lesion. A long bone survey done at the same time showed evidence of metastatic disease. Intravenous pyelography five days after the air study revealed a neuroblastoma on the right side (Fig. 5). Everything about this patient was carried out in backward fashion. Diagnosis at the primary site was made only after metastases had appeared.

FIG. 5.—Case 5. Neuroblastoma on right. Diagnosis made only after metastases produced increased intracranial pressure

In summary, concerning neuroblastomas, you have seen a textbook picture of the suprarenal position of a neuroblastoma above the kidney and a variation of the neuroblastoma below the kidney. One tumour displaced the ureter anteriorly and medially while still another displaced the ureter laterally and indented the bladder. Calcium was present in some but not in all flat films.

The histories of these patients included weight loss, pain, fever of unknown origin, diarrhoea and anaemia. In so far as similar syndromes are concerned, neuroblastoma mimicked poliomyelitis, arthritis and rheumatic fever. Such are the vagaries of the neuroblastoma.

One of our residents married one of our nurses and in the course of time produced a child. By this time the young physician had moved to another city in the course of his training and when the child was born with an abdominal mass, the mass was assumed to be spleen because of a Rhesus incompatibility on the part of the parents. The mother took her baby into a rural area of Pennsylvania where the local physician watched the mass grow in size until it reached the umbilicus, whereupon the infant was referred to one of our medical confrères for evaluation of splenomegaly. It was obvious on examination of the abdomen that the mass in question was a retroperitoneal tumour and not spleen, and following the philosophy of management already outlined and spurred on additionally by the fact that the parents of the patient were our friends, the child was operated upon about six hours after admission to hospital. The tumour was a neuroblastoma and not only inoperable in the usual sense of the word by being wrapped around the hilum of both kidneys, but there were many metastases, multiple and small, covering the entire surface of the liver. Biopsy of both the primary and metastatic lesions showed an immature variety of neuroblastoma. Because of the helpless feeling of operating upon an impossible situation in a child of a friend, we attempted to scoop out what tumour we could, actually used very bad cancer surgical technique, and advised no X-ray therapy because we thought the child would not benefit from it and that the sooner he died the better for all concerned. Two weeks later his subcutaneous tissue was the site of multiple nodules such as one sees in a terminal leukaemia. To make a long story short, 13 years have gone by and this child is alive and well, has no abdominal tumour, even when his abdomen is palpated under anaesthesia, and his intravenous pyelogram shows no major abnormality. It was this patient and his subsequent course that led us to withhold radiation therapy in a neuroblastoma postoperatively and, in a sense, we have built up a control series with surgery and no X-ray or chemotherapy, the mortality of which compares favourably with any series reported from our country in each of which X-ray therapy is given a major share of the credit for what survival there is.

In 1955 I reported a survival of 30·8% in the surgical management of neuroblastoma, that is 12 survivals of 44 patients. After presentation of this experience to several groups, the consensus was that if I had irradiated the patients as well I would have had an even better survival rate and, therefore, we planned a series of surgery followed by radiation. The next eight patients died following radiation and although eight is not a large number, it is a sufficiently large number for the surgeon to assess and perhaps change his tactics. When we reviewed the situation in 1958 we found that all the patients reported alive in 1955 were still alive in 1958 and one reported to be dead in 1955 (due to faulty follow-up) was indeed alive in 1958, and our survival was not 30·8% but 33·3% with a follow-up of 4 years 2 months minimum and 12 years maximum. Since reverting in early 1958 to the surgical extirpation of neuroblastomas without the benefit of radiation therapy, we again have several patients who seem on their way to the closest thing to a cure that one can talk about in the treatment of malignant disease in children.

The following are some examples of embryoma of the kidney.

Case 6. A 2½-year-old boy had an asymptomatic left upper quadrant mass found on routine physical examination by his paediatrician. An intravenous pyelogram showed a typical Wilms' tumour. The boy was immediately operated upon and treated with irradiation but metastases appeared in the liver and lung fields. The child died approximately one year after the appearance of metastases. In this instance the intravenous pyelogram revealed the usual garbled shadow produced by the dye in a Wilms' tumour (Fig. 6). In spite of the fact that this tumour was small, it metastasized early.

Case 7. R.K. This 7-month-old girl entered hospital because her mother had felt a huge abdominal mass while giving the child a bath. The mother, a competent observer, claimed that the tumour was not present the day before and the presumption is that haemorrhage into the tumour produced a change in size which led to its palpation. An intravenous urogram was done and this study revealed an intrinsic tumour in the left kidney (Fig. 7). The mass was removed and the child was given 2,500 R tissue dose to the midline. Seven years later she is alive and well with no evidence of metastases. Here, a huge tumour treated in the same way as in the previous patient showed no evidence of metastasis and has a seven-year cure.

FIG. 6.—Case 6. Small Wilms' tumour with early metastasis.

FIG 7.—Case 7. Huge Wilms' tumour without metastases; seven-year survival.

Case 8. W.W. This 3-year-old boy went to see his family doctor for a routine prophylactic injection one week before admission. The physician, an unusually thorough gentleman, quickly palpated the abdomen as part of a routine check-up and felt the abdominal mass. Intravenous pyelography revealed a typical distorted and garbled opaque shadow indicating an intrinsic mass in the kidney (Fig. 8). The boy is alive and well eight years after surgery and X-ray therapy.

Case 9. E.Y. was a 1-year-old girl, who two weeks before admission was found by her father to have a mass on the right side. During the intervening two weeks her right side had become firm and rigid. Laxatives and enemas had been given in an attempt to remove what her father suspected was a faecal impaction. After surgery the patient developed metastases and died rather promptly. The anterior-posterior view in this child is not helpful. A lateral film was needed for a differential diagnosis between a neuroblastoma and a Wilms' tumour (Fig. 9).

Case 10. S.O. This 11-month-old girl was sent into hospital because someone thought he felt a mass in the left upper quadrant. At our institution no mass could be felt but intravenous pyelography was undertaken to rule out any doubt. This showed a very minimal distortion of the left renal pelvis. Our best films on this child are not available, but Fig. 10 indicates the area in which we were concerned. It was decided to do a nephrectomy rather than cut into the tumour, if such were present, for diagnosis, and when the kidney was removed it looked like a normal organ. When it was sectioned, however, there was a 2 cm. nodule just beneath

FIG. 8.—Case 8. Typically distorted pelvis by Wilms' tumour; eight-year survival.

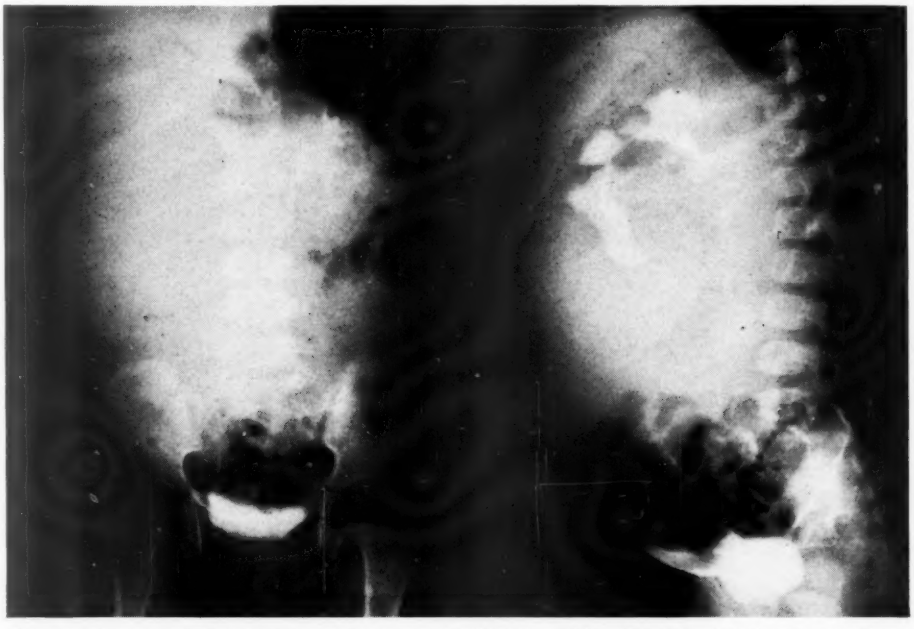

FIG. 9.—Case 9. Wilms' tumour. A-P view not helpful in making diagnosis; lateral film needed for differential diagnosis between Wilms' tumour and neuroblastoma.

FIG. 10.—Case 10. Intravenous pyelogram showing crescentic displacement of calyx and pelvis on left due to a small Wilms' tumour. Compare with Fig. 11.

the renal pelvis. This proved to be a Wilms' tumour and the smallest one we have encountered clinically. The patient is alive and well four and a half years post-operatively. X-ray therapy was given.

Case 11. D.P. This 3-year-old girl with pyuria and fever was investigated for pyelonephritis by intravenous pyelography. In this study the same distortion of the left renal pelvis is noted as that seen in the previous patient's films. Note how the carbonated beverage has not only given better definition to the intravenous pyelography but has depressed the kidneys by intragastric gas pressure a distance of one vertebral body (Fig. 11). Nephrectomy was carried out in this child and, to our great surprise, the distortion of the pelvis was by an anomalous pyramid. This is the first anomalous pyramid we have encountered and the second such X-ray picture in about 17,000 pyelograms. Obviously, this is not an adequate method of making a diagnosis of a small Wilms' tumour and on our next occasion we will resort to arteriography.

In summary, all the Wilms' tumours presented were asymptomatic. One such tumour was found on a routine physical examination by a paediatrician; another was found by a mother who claims it was not there the day before; a third was found when a local physician did a hurried physical examination before giving a prophylactic vaccine; a father discovered a fourth tumour and, finally, the fifth patient was thought to have a mass even when none could be palpated, but nevertheless proved to have the smallest clinical Wilms' tumour in our series.

Finally, to shake one's confidence in any diagnostic procedure, a normal kidney with an anomalous pyramid mimicked almost identically a Wilms' tumour.

None of these patients had haematuria, a sign which is usually interpreted as meaning a very poor prognosis because of early penetration of blood vessels. However, our own experience indicates that this might also be a very early sign and lead to a happy prognosis.

Although X-ray therapy is recommended as a routine post-operatively, patients are individually managed and when the tumour is small, the patient young, and the surgery atraumatic, no X-ray therapy is given.

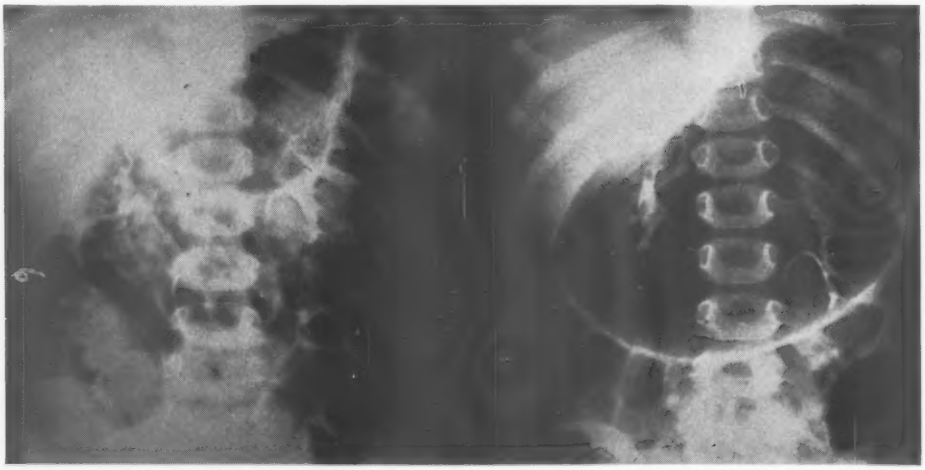

FIG. 11.—Case 11. Intravenous pyelogram showing crescentic displacement of calyx and pelvis on left due to an anomalous renal pyramid. Compare with Fig. 10.

Before leaving malignant tumours, we should again remind ourselves of the rapid growth of these two just discussed and the fact that the usual behaviour of adult cancer is crowded into a much shorter time in the paediatric age group. What is thought of as a five-year cure can usually be telescoped into a 14-month period in reference to the two tumours just discussed.

As to their importance, they account for 20% of all malignant tumours in children and 40% of those against which we have at the moment a satisfactory weapon.

The following are some other abdominal tumours which occasionally present themselves for differential diagnosis.

Case 12. F.L. A 2½-year-old girl entered hospital because of an anaemia. The evacuation of some of the barium enema revealed an abnormal air-filled bowel in the right upper quadrant which, when we did the small bowel study, filled with barium. The patient was sent home but returned bleeding severely from the rectum and was operated upon. Her lesion proved to be an ulcerated duplication of the ileum (Fig. 12).

Case 13. R.S. was a 5½-month-old girl who at the age of 3 weeks was found to have a large liver. Nothing was done for this child until she came to our hospital at 5½ months when she was really a huge abdomen with a small baby attached. She was completely dehydrated from vomiting and could not hold anything in her stomach. A survey film revealed a huge abdominal mass on the right side thought to be liver. With some barium in the stomach the edge of the mass could be seen.

FIG. 13.—Case 13. Tumour of liver, affecting chiefly right lobe. Haemangioendothelioma.

An intravenous urogram proved that this was not intrinsic to the kidney (Fig. 13). At operation it was

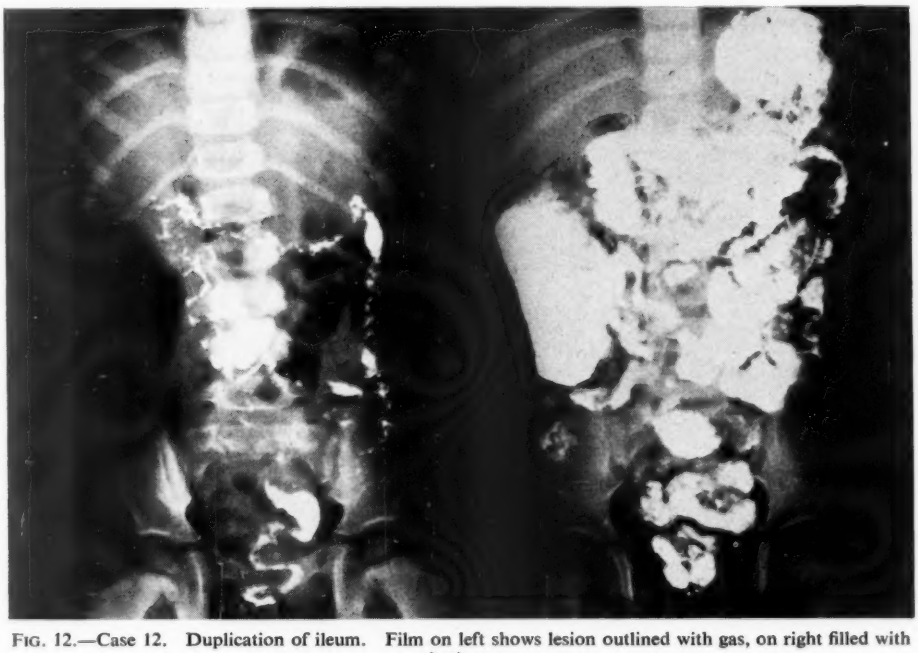

FIG. 12.—Case 12. Duplication of ileum. Film on left shows lesion outlined with gas, on right filled with barium.

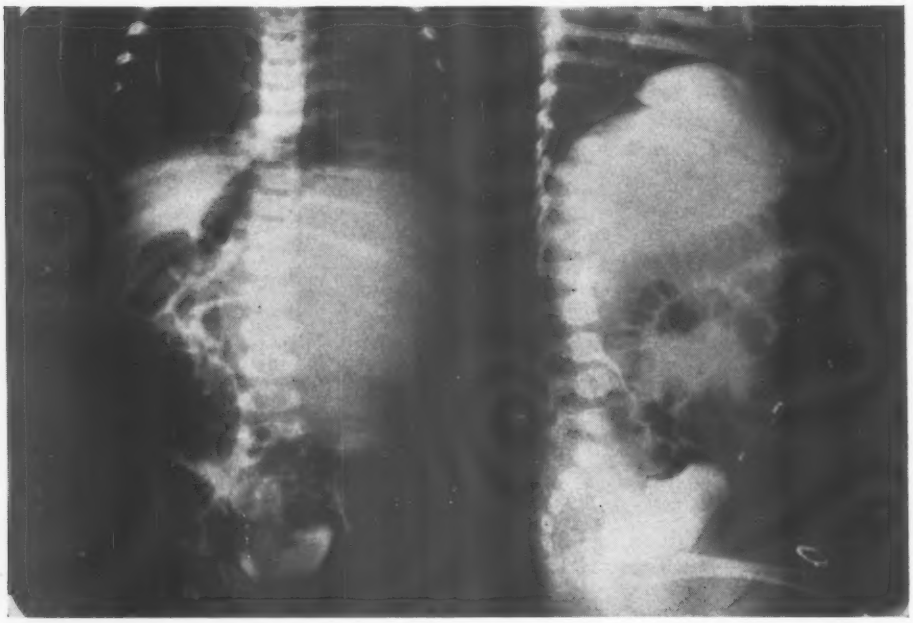

FIG. 14.—Case 14. Huge hepatoblastoma of left lobe before radiation therapy.

thought that we were dealing with a primary carcinoma of the liver but a piece taken for biopsy was reported as being a benign haemangio-endothelioma. The child received 1,000 R tissue dose to the liver which had shrunk to normal size in eight months. The child is alive and well several years later.

Case 14. J.M. was a 2½-year-old boy with progressive enlargement of his abdomen of one month's duration. The flat film showed a huge mass and the intravenous pyelogram showed the kidney to be depressed so that a diagnosis of neuroblastoma was made (Fig. 14). At operation the tumour was found to be intrinsic to the liver and the mass seemed to involve both right and left lobes. The child was given 3,200 R tissue dose in 33 days through a portal 13×15 cm. Eight weeks after X-ray treatment the child was re-explored and the tumour was found to lie in the right lobe only. A right hepatic lobectomy was carried out and the child is alive and well five years post-operatively. The histological diagnosis was hepatoblastoma.

Case 15. N.L. This 4½-year-old girl had a six-week history of lower abdominal pain which eventually became epigastric. Three weeks before admission she became jaundiced and had clay-coloured stools. The gastro-intestinal series of radiographs undertaken at another hospital showed a wide duodenal loop which would have suggested in an adult carcinoma of the head of the pancreas (Fig. 15). The child was operated upon in our institution five days after the study elsewhere and she did indeed have a tumour in the region of the head of the pancreas which proved on histological section to be a reticulum cell sarcoma. The tumour involved the coeliac axis and was not resectable. The child received 2,800 R tissue dose over a portal of 15×15 cm. over a period of three weeks. She did well for a while but six months after operation she came into hospital in coma

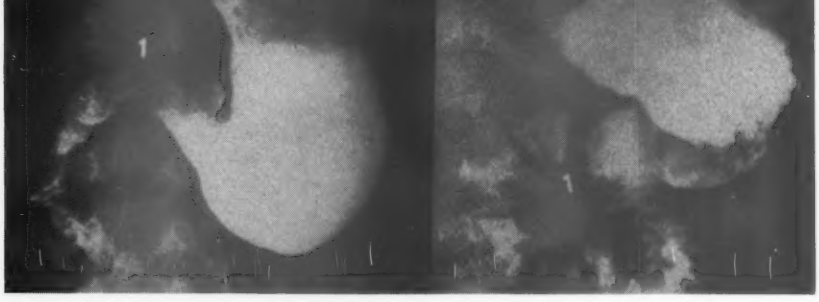

FIG. 15.—Case 15. Widening of duodenal loop caused by reticulum cell sarcoma simulating classical carcinoma of head of pancreas.

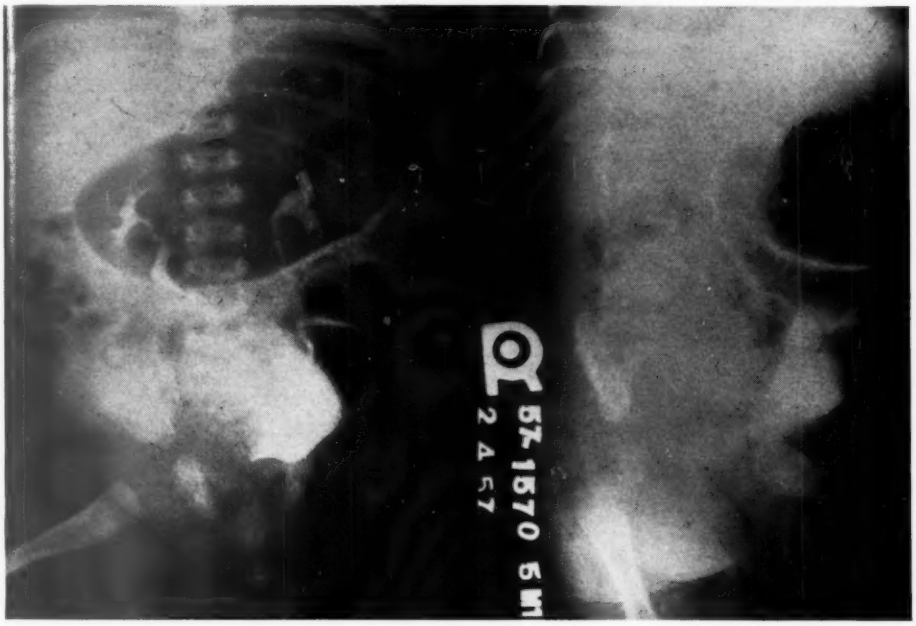

FIG. 16.—Case 16. A-P and lateral intravenous pyelogram for abdominal mass which proved to be iliac abscess secondary to an infected circumcision.

and died. At autopsy she was found to have radiation nephritis as the cause of her death.

Case 16. This 2-week-old boy had a swollen leg and prominent veins over the right lower quadrant. It was thought that this would be a neuroblastoma on the basis of clinical impression. It proved, however, to be a staphylococcal abscess secondary to a dirty circumcision and inguinal adenitis (Fig. 16).

Case 17. J.A. Eleven days before this examination this 6-year-old boy was struck in the epigastrium by the handlebars of a bicycle. From that time on he had upper abdominal pain and vomiting. His serum amylase was 1,500 units. Original films show the appearance of a mass in the vicinity of the pancreas which had not altered when repeated two weeks later (Fig. 17). The child was treated by judicious neglect and had no further difficulty.

Case 18. E.T. This 11-year-old boy complained of jaundice of one month's duration and loss of appetite. He entered the Children's Hospital of Philadelphia with a temperature of 105° F. and abdominal pain; gastrointestinal series of radiographs showed his common bile duct to be large as indicated by the depression of the duodenum (Fig. 18). The child was operated upon and a huge gall bladder and dilated common duct were found. The duct was opened and there extruded a number of flimsy structures resembling nasal polyps. A T-tube was left in the common bile duct and a cholangiogram indicated dilatation of the entire intrahepatic biliary tree. The patient died two months after operation and at autopsy had a large abdominal tumour as well as metastases in the abdomen, pelvic bones and liver. This, of course, is the classical early and late picture of a rhabdomyosarcoma.

Case 19. C.B. was a 4-year-old female who was admitted to hospital because of abdominal pain of one week's duration. An abdominal mass could be palpated in the left upper quadrant separate from the left kidney. At operation this proved to be a teratoma which was almost a complete embryo with arm and leg buds. It was necessary to remove the left kidney and left adrenal gland in the course of the dissection (Fig. 19).

FIG. 17.—Case 17. Displacement of bowel caused by pseudocyst of pancreas 11 days after epigastric injury.

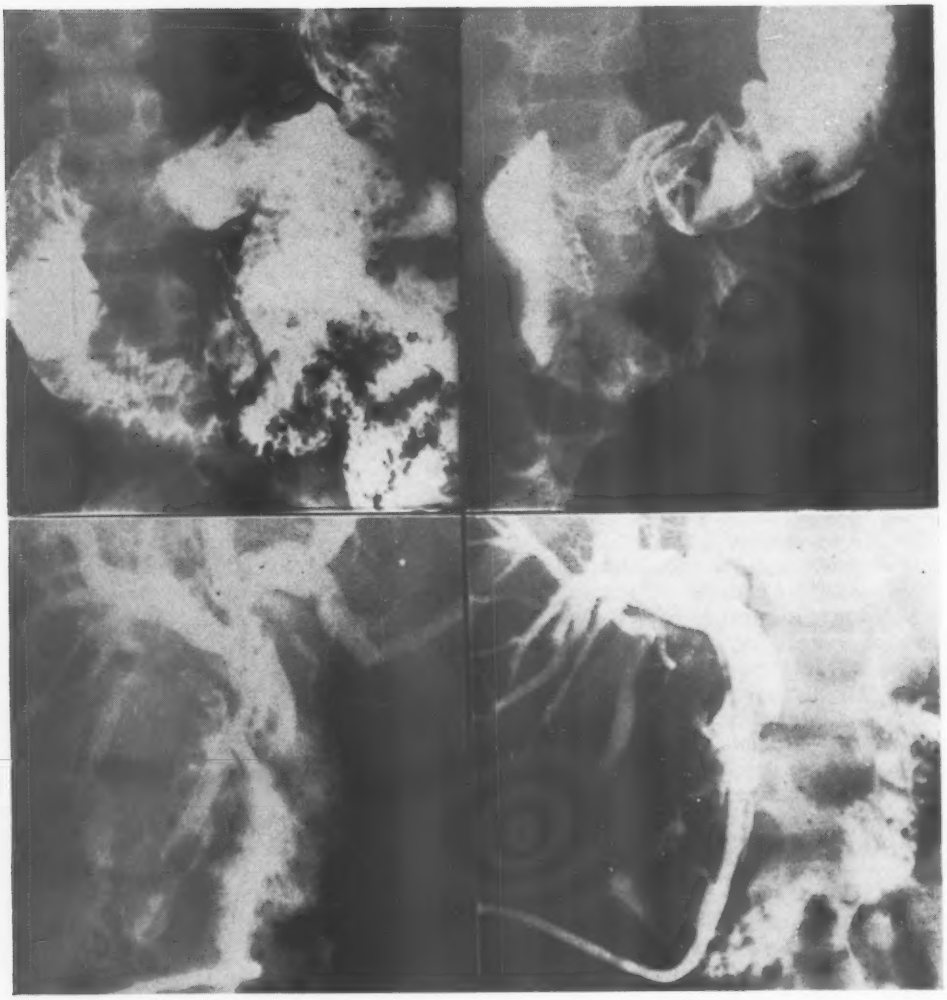

FIG. 18.—Case 18. Upper gastro-intestinal series showing interruption of barium shadow in duodenum due to an enlarged common bile duct. Cholangiogram shows dilatation of common bile duct and its proximal intrahepatic radicals.

FIG. 19.—Case 19. Intra-abdominal teratoma attached to left kidney and adrenal gland, with X-ray of teratoma following extirpation.

FIG. 20.—Case 20. Abdominal mass containing faecolith of calcific density; appendiceal abscess.

Case 20. D.P. was a 5½-year-old male with a two-week history of abdominal pain. In this two weeks the pain had become worse and the child had begun to vomit. At the time of examination there was severe abdominal tenderness and a mass could be palpated in the right lower quadrant. The films revealed a large soft tissue mass and a calcified mass within the large soft tissue density. This proved to be an appendiceal abscess with a faecolith (Fig. 20).

Case 21. T.E. A 6-month-old girl entered the hospital with a referring diagnosis of Wilms' tumour. On palpation of the abdomen there was a huge mass and, since palpation in the left upper quadrant moved the mass in the right upper quadrant and vice versa, the presumptive diagnosis was a Wilms' tumour in a horseshoe kidney. A flat plate of the abdomen revealed what looked like an old barium enema of the colon. Since there was no such history, it was presumed that the shadow represented calcifying faeces. A barium enema was carried out as a terminal aganglionic segment indicating megacolon was suspected. It was impossible to wash out the faecal impaction and at operation a colostomy was done. Six months later at the time of attempted pull-through procedure two lumina were noted in the bowel. It was then understood that we were dealing with a duplication of the colon. In the original films it was possible to see an air column streaking past the impaction of calcific density. The bowel was re-anastomosed after resecting the common wall between the two duplications (Figs. 21, 22, 23).

Case 22. L.S. This 3-year-old girl came into hospital because of pain in her left hip of one year's

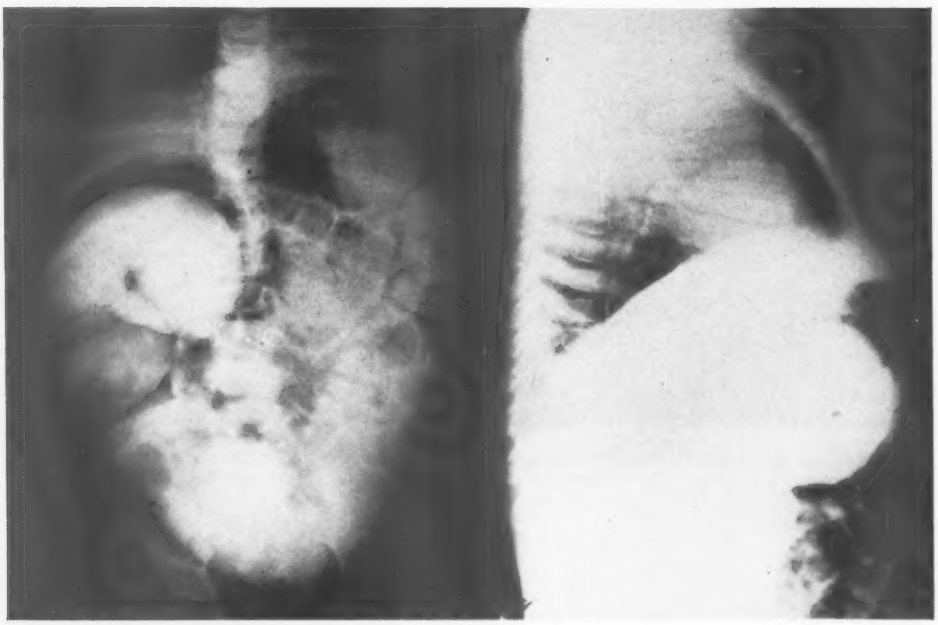

FIG. 21.—Case 21. Faeces of calcific density in duplication of colon with blind distal end.

FIG. 22.—Case 21. Barium enema of patient in Fig. 21. Note air column to left in lateral film indicative of true colon.

FIG. 23.—Case 21. Post-operative barium enema showing duplication proximally and single lumen distally.

FIG. 24.—Case 22. Post-operative film showing catheter in retroperitoneal cavity communicating with duplication of stomach (neurenteric cyst?).

duration. She had been studied in several hospitals for this period of time. The films of her pelvis were normal but a mass lesion was found in the left mid-abdomen which seemed to be extrinsic to the left kidney. At operation there was a retroperitoneal mass lying beneath the mesentery of the colon. On aspiration this produced thick material resembling motor oil which was evacuated. It was then obvious that an hour-glass constriction connected this sausage-shaped mass with a much larger mass which lay within the psoas muscle. This latter mass also contained the same thick grumous material.

Further dissection revealed that the initial mass was a cystic structure with a lining somewhat resembling that of the stomach. It perforated posteriorly into a pseudocyst of the psoas muscle. Microscopical sections revealed gastric mucosa. This was a duplication of the stomach without attachment to any other intestinal viscus (Fig. 24). In all likelihood with further dissection this lesion could have been proved to be a neurenteric cyst.

One could continue to discuss abdominal tumours for a considerable period of time, calling upon experience with the commonplace as well as the bizarre. I trust these few examples of abdominal masses have served to place in proper focus the more serious and challenging aspect of the management of abdominal tumours in children, namely those malignant lesions which carry such a forbidding mortality.

OVARIAN NEOPLASMS IN CHILDREN*

BY

ISABELLA FORSHALL

From the Royal Liverpool Children's Hospital and Alder Hey Children's Hospital, Liverpool

Just over 100,000 cases have been admitted to the two main Liverpool Children's Hospitals during the last 10 years; amongst these were 21 children with ovarian new growths (Table 1).

TABLE 1
OVARIAN NEW GROWTHS, 1949-59

Tumour	No. of Cases	Left	Right
Cystadenoma	2	1	1
Teratoma:			
(*a*) Benign cystic	12	7	5
(*b*) Solid	1	—	1
Tumours of special morphology ..	3	3	—
Tumours of doubtful origin .. (one case had bilateral tumours)	3	3	1
Total	21	14	8

Cystadenoma

Cystadenoma, which accounts for 40-50% of all ovarian new growths, is a tumour of adult life, and uncommon in patients under 20 years of age. We have seen two cases, a girl (E.G.) of 13 with a right-sided, thin-walled, unilocular cystadenoma measuring 17 × 13 × 10 cm., and a 12-year-old child (M.O.) with a small, left-sided, multilocular cystadenoma; neither of these two girls had menstruated.

Teratoma

Including all age groups, teratomas constitute 10-15% of ovarian tumours, but over 50% of the tumours of children are of this type. Willis (1955a) succinctly defines teratomas as 'embryonic tumours of pluri-potential, regionally non-specific tissue'. They possibly originate in foci of plastic polyvalent tissue, which escape the influence of the primary organizer (Willis, 1955b). Ovarian teratomas are arbitrarily divided into:

(*a*) the common, benign, largely cystic tumours, in which tissue differentiates and matures synchronously with the tissues of the host; and

(*b*) the much less common solid or polycystic tumours, in which a great variety of tissue in different stages of maturity is found. They may grow rapidly and are usually malignant.

Though benign cystic teratomas consist largely of ectodermal tissue, skin with sweat glands and hair follicles, tooth buds or teeth and sebaceous material, endodermal and mesodermal tissue is always represented. Cartilage, muscle, intestinal and bronchial epithelium and nervous tissue are common. The contents of the cyst may be mucous or cerebrospinal fluid, in addition to or to the exclusion of the more usual sebaceous material.

The right ovary is affected more often than the left, and in 10% of cases there are bilateral tumours.

Radiological examination shows teeth, cartilage, bone or calcification in the cyst wall in 75% of cases.

Ovarian teratomas have been described in infants. They are, however, rarely encountered in children under 3 years of age. In a child the cyst is seldom larger than the patient's head.

Children with teratomatous cysts present in three ways: with enlargement of the abdomen; with abdominal pain, which may be either continuous or intermittent; or as urgent emergencies with torsion of the cyst pedicle.

Torsion is the commonest complication and is recorded in 1 in 4 or 1 in 3 of large series of cases (Peterson, Prevost, Edmunds, Hundley and Morris, 1955).

The development of carcinoma in a benign cystic teratoma is not uncommon in adults, usually in those past middle life, in whom the tumour has probably been present for a long time. It is doubtful whether this complication ever occurs before puberty.

We have seen 12 children with teratomatous cysts; the main features of these cases are summarized in Table 2.

Solid or polycystic teratomas are, by and large, rapidly growing and highly malignant. They tend to metastasize via the blood stream to the lungs.

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

TABLE 2
BENIGN CYSTIC TERATOMAS

Case	Age (yr.)	History	Radiograph	Torsion	Side	Histology
S.J.	3	4 wk. pain, vomiting, constipation	Positive	Yes	Left	Teratomatous cyst; sebaceous material, hair, teeth, muscle
E.L.	10	3 yr. pain left-sided	Positive	No	Right	Teratomatous cyst; sebaceous material, hair, teeth
R.S.	5	Increasing abd. swelling; pain	—	No	Right	'Dermoid cyst', very large
H.C.	8	Increasing abd. swelling	—	Yes	Left	'Dermoid cyst'
C.P.	10	3 mth. intermittent left abd. pain; vomiting; pain on defaecation	—	Yes	Right	'Dermoid cyst', twisted with one horn of bicornate uterus
J.R.	7	Abd. pain and vomiting	Negative	Yes	Left	'Dermoid cyst'
C.W.	10	Abd. enlargement, pain	Positive	No	Left	Teratomatous cyst; skin, hair, cartilage, brain
B.G.	11	2 yr. abd. pain; nausea	Negative	No	Left	'Dermoid cyst'
W.T.	12	2 yr. vague pain; 3 wk. severe pain	Positive	No	Left	Teratomatous cyst; skin, teeth, hair, bone, cartilage, lung, nervous tissue
R.C.	5	Enlargement of abdomen since birth	Positive	No	Right	Teratomatous cyst; 12 × 1 × 6 in.
P.M.	11	Few mth. intermittent abd. pain	Positive	No	Left	Teratomatous cyst; calcified wall, bone, muscle, tooth, columnar epithelium 13 × 10 × 8 in.
L.S.	13	Few days left-sided abd. pain	Positive	No	Right	Teratomatous cyst; hair, sebaceous material, cartilage, mucous glands, columnar ciliated epithelium; cyst lined squamous epithelium 10 × 6 × 4½ in.

Very rarely precocity and uterine bleeding have been associated with malignant teratoma containing areas of chorionic carcinoma.

We have seen only one solid teratoma; it occurred in a 12-year-old girl (J.N.) who had a large, easily visible, abdominal swelling. At operation there was bloody peritoneal fluid and the tumour had transgressed its capsule at two points; it was considered to be malignant. The pathologist, however, reported that, though the tumour contained the typical conglomeration of tissue, there was no definite evidence of malignancy. The child is well four years post-operatively.

Tumours of Special Morphology

(a) Granulosa Cell Tumour or Granulosa Cell Carcinoma, and Theca Cell Tumour. These tumours contain cells similar to those of the zona granulosa and theca interna of the normal ovary. Willis (1948) believes that they originate in normal follicular tissue or from the bi-potential formative ovarian stroma. Granulosa cell tumours usually contain some theca cells and, though theca cell tumours are more often 'pure', they often contain areas in which granulosa cells can be found. The rare luteal tumour causing similar symptoms is probably a granulosa-theca cell tumour which has undergone luteinization.

In keeping with tumours of other endocrine glands, granulosa and theca cell tumours may, or may not, produce hormones.

Granulosa cell tumours are said to constitute 10% of all solid ovarian tumours; 5% of the total number recorded have occurred in children (Morris and Scully, 1958a). This estimate of the relative frequency of the tumour in children is probably too high. A hormone-secreting tumour in a child would almost certainly be published, whilst such a tumour in an adult might well cause less interest. Wilkins (1957) states that 33 granulosa cell tumours causing precocious puberty in children of 7½ years or under have been recorded. He has followed the exacting discipline of paediatric endocrinology for 20 years and has seen only a single case. Morris and Scully (1958b) state that 60 granulosa cell tumours and four theca cell tumours have caused precocious sex changes in prepubertal children. The disparity between 33 and 60 probably reflects a difference of opinion between the two authorities about the age at which sex changes are considered to be precocious. The youngest reported case of a granulosa cell tumour is a 14-week-old infant with bilateral tumours (Zemke and Herrell, 1941).

Uncommon as the granulosa cell tumour is, it is the most frequent ovarian cause of sexual precocity. The oestrogen-secreting tumour causes enlargement of the uterus, endometrial hyperplasia and bleeding, which may be slight or profuse, continuous or intermittent. In about half the reported cases it has been cyclical. Bleeding may occur only after removal of the tumour (oestrogen-withdrawal bleeding); on the other hand, it has often been the initial symptom; it is anovular and the other ovary remains normal for the child's age. There is development of the vulva and vagina and the vaginal cytology is of adult type.

Secondarily induced development of the breasts and growth of sexual hair commonly occur but are not invariable. Body growth is stimulated and the child is likely to be tall for her age.

Unfortunately few oestrogen assays have been made in children; in those recorded, the urinary oestrogen figures have varied from normal adult to very high levels (Wilkins, 1957).

As first pointed out by Gross (1953), all granulosa cell tumours, which have caused symptoms of oestrogism in children, have been readily palpable on abdominal examination. This is an important point in the differential diagnosis of bleeding or of sexual precocity.

In adults, symptoms of hyperoestrinism have been produced by tumours as small as 1·5 cm. in diameter. It is therefore possible that cell for cell the granulosa cell tumours of children produce less oestrogen than the tumours of adults.

In children under 8 or 9 years, the age at which the ovary normally begins to undergo pre-pubertal changes, regression of sexual development takes place after removal of a granulosa cell tumour. In children over this age little change occurs apart from cessation of bleeding and reduction in the size of the uterus.

No long-term follow-up of cases which have had granulosa cell tumours removed in childhood is available. It is, however, known that a second tumour may develop in the other ovary many years after a granulosa cell tumour has been removed, and that intraperitoneal recurrences may appear a long time after a patient is thought to be cured (Diddle, 1952). Distant metastases may occur but are not common. The mortality for granulosa cell tumour in adults is about 50% and the longer the follow-up the higher the mortality. The histology of the tumour may give some help in prognosis (Kottmeier, 1952).

We have seen only one child (C.E.) with a granulosa cell tumour (Table 3). She was admitted aged 11 months with a cystic, easily palpable tumour which had undergone torsion. Enlargement of the breasts was just appreciable, and there was a faint down of dark pubic hair. There was no history of bleeding, but she had a slight blood-stained vaginal discharge for 48 hours after operation.

(b) Arrhenoblastoma, Hilar Cell or Sertoli-Leydig Cell Tumour. These tumours, which characteristically cause masculinization, are rare at any age, and excessively rare before puberty. An arrhenoblastoma in a girl of 11 years with symptoms of masculinization is, however, described (Thomas, Fisher, Turnbull and Krieger, 1952) and Morris and Scully (1958c) mention a Leydig cell tumour causing virilism in a girl of 4 years.

(c) Germinoma. This is a non-hormone-secreting tumour, composed of cells of embryonal type, resembling the sexually undifferentiated germ cells of the early gonad.

Disgerminoma of the ovary is histologically indistinguishable from seminoma of the testicle. The former has a high incidence in pseudo-hermaphrodites and patients with hypogonadism, and seminoma has a predilection for incompletely descended testes; either tumour is occasionally bilateral. Interesting differences are that, in spite of seminoma being more easily diagnosed whilst the tumour is small, the mortality for seminoma is higher than that for disgerminoma. The difference in age incidence is very remarkable. Disgerminoma is a tumour of the young; three-quarters of the cases recorded have been under 30 years and half under 20 years, though no instance of the tumour has been

TABLE 3
TUMOURS OF SPECIAL MORPHOLOGY

Case	Age	History	Clinical Findings	Treatment	Diagnosis	Side	Result
C.E.	11 mth.	Abdomen always prominent; rapid increase last few days; acute abdominal pain; vomiting	Large cystic lower abd. tumour; definite slight mammary enlargement; faint down of dark pubic hair	Oophorectomy	Granulosa cell tumour; large polycystic; uterus enlarged, other ovary normal; torsion	Left	Post-operative uterine bleeding; complete regression of sex changes; well 3 yr.
J.T.	12 yr.	Abdominal pain; dysuria; pyrexia	'As big as a child of 8 yr.'; large solid tender mass left lower abdomen and pelvis	Excision of tumour, uterus, ovary, part of bladder, sigmoid colon and parietal peritoneum; radiotherapy	Disgerminoma; solid tumour as big as large grapefruit; adherent to and infiltrating pelvic organs and parietal peritoneum	Left	Still very small; well 2½ yr.
J.D.	13¼ yr.	(At 3 yr. undescended testes, right gonad biopsy, testes, repair hypospadias); acute abdominal pain 6 days	Large lower abd. tumour; urinary 17-ketosteroids 4 mg./day; sex chromatin —negative, male	'Oophorectomy'; radiotherapy	Germinoma; ?disgerminoma; ?seminoma; large solid tumour, small uterus, fallopian tubes and broad ligaments; torsion	Left	Well 6 mth; growth of penis and sexual hair

recorded in a child under the age of 7 years. Seminoma is most frequent early in the fifth decade, very rare before 20 years, and the youngest case recorded was 16 (Bell, 1938).

Disgerminoma is a smooth, solid tumour, grey or greyish-pink in section. It has a tendency to undergo necrosis, to transgress its capsule and invade neighbouring pelvic organs and sometimes lymphatic glands. Distant metastases occur, but uncommonly. In cases followed up over long periods the mortality is about 50% (Morris and Scully, 1958d).

Our first case (J.B., Table 3) apart from her tumour showed no abnormality except that she was very small for her age. She is chromatin-positive.

The second case (J.D., Table 3) occurred in a child who is chromatin-negative. The gonad on the left was entirely replaced by tumour, so that it is not possible to know whether it was an ovary, a testis or an ovo-testis. The tumour was intra-abdominal and there was a uterus and two fallopian tubes; the other gonad is, however, an incompletely descended testis. The child's development since the tumour was removed appears to be conforming to the male pattern. In view of the patient's age, this tumour is best designated a germinoma rather than either a seminoma or disgerminoma.

Tumours of this group which, from their morphology, would be expected to secrete oestrogens or androgens may be inactive; less commonly, a tumour containing granulosa cells produces androgens and a tumour containing Sertoli-Leydig cells causes feminization.

Germinomas, which are characteristically non-hormone-secreting, have occasionally produced sex hormones.

Tumours of Doubtful Origin

Three cases have been grouped under this heading (Table 4).

One was a highly malignant anaplastic carcinoma in a girl (J.T.) of 13 months, which conformed histologically to the tumour described by Schiller (1939) as a mesonephroma. Morris and Scully (1958e) include this growth amongst the malignant teratoid tumours.

The second was a large, solid tumour in a girl (J.C.) of 8¾ years. Histologically it was a highly malignant undifferentiated carcinoma. The possibility of its being a hormonely inactive granulosa cell carcinoma, or even a disgerminoma, is not excluded: in favour of one or other of these diagnoses is the fact that the child is well four and a half years after operation and radiotherapy.

The third child (V.T.) presented during life, and at autopsy, a picture so confusing that the case is left without comment.

Secondary malignant tumours of the ovary are common in adults, but in children they are very rare; Grob (1957) has described bilateral ovarian tumours secondary to lymphosarcoma of the neck. In this case a very careful search at autopsy disclosed no alternative primary growth.

Treatment

An ovarian tumour should be removed, and the sooner the better; it may be malignant and a few days may make a difference in prognosis. A large incision should be made, and the pedicle of the tumour should be clamped at the first possible

TABLE 4

TUMOURS OF DOUBTFUL ORIGIN

Case	Age	History	Clinical Findings	Treatment	Diagnosis	Side	Result
J.T.	13 mth.	Enlargement of abdomen	Firm, mobile abdominal tumour	Oophorectomy	Anaplastic carcinoma (mesonephroma)	Left	Death 4 mth. Abdominal metastasis
J.C.	8¾ yr.	Enlargement of abdomen	Large, solid, lower abdominal tumour	Oophorectomy; radiotherapy	Solid; tumour through capsule; blood and clumps of tumour cells in peritoneal fluid; undifferentiated carcinoma; ?? granulosa cells. W. 435 g.	Left	Well 4½ yr.
V.T.	13 yr.	2 mth. general ill health, pain, anaemia, intestinal bleeding	Abdominal and pelvic mass; ascites; clinical features and blood picture of widespread malignant process	Radiotherapy started but discontinued	Autopsy: bilateral ovarian tumours; search revealed no alternative primary growth. Histological features of anaplastic carcinoma rather than malignant reticulo-endothelial disorder; probably primary ovarian growth	Left	Death

moment to prevent dissemination of malignant cells via the blood stream.

The fallopian tube should be preserved in obviously simple cystic tumours. The second ovary should be examined; it may contain a small teratoma or granulosa cell tumour, removal of which by dissection will preserve some ovarian tissue.

Cases of granulosa cell tumour and disgerminoma have recovered when the tumour has spread beyond its capsule and invaded other pelvic organs so that radical excision is justified and may be rewarding.

There is little authoritative guidance about when to use, and when not to use, radiotherapy, and the decision may be very difficult. Not only will irradiation cause sterility, but growth and the pattern of growth may be impaired.

It is probably true to say that anaplastic carcinomas, malignant teratomas and tumours which histologically resemble chorionic carcinoma will be little influenced by radiotherapy.

Granulosa cell tumours and disgerminomas are radio-sensitive, and there is definite evidence that in adults the prognosis, after removal of these tumours, is improved by radiotherapy (Santesson, 1947). Therefore, if it has been necessary to remove as well as the tumour the uterus and second ovary, or if the peritoneal fluid contains tumour cells, or if the report of the pathologist suggests a highly malignant growth, radiotherapy should be given.

If the tumour is intracapsular and the pathological report is favourable, *x* rays should be withheld.

Girls who have had both ovaries removed, or one removed and the other destroyed by *x* rays, should have the benefit of endocrine treatment at 13 to 16 years of age so that they may, as far as possible, conform to the female pattern.

The literature shows that ovarian tumours are more frequently right- than left-sided, and this is especially true of teratoma and disgerminoma.

In this series of 21 cases (22 tumours), 14 were left-sided and eight right-sided (Table 1). This emphasizes the fallacies inherent in conclusions based on small series of cases.

I gratefully acknowledge the help of Dr. E. G. Hall and Dr. J. S. Elwood, pathologists to the two hospitals, and thank Mr. P. P. Rickham for allowing me to include some of his cases.

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PRIMARY TUMOURS OF THE LIVER IN INFANTS AND CHILDREN*

BY

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Primary liver tumours occur in infants and children with sufficient frequency to justify careful evaluation of current techniques in diagnosis and management and to review the pathological classification of this group of neoplasms. In the past nine years (1950-1958) 15 such cases have been diagnosed at the Columbus Children's Hospital, all presenting as clinical problems; an analysis of these cases forms the substance of this report. During the same period of time 46 cases of neuroblastoma and 17 cases of embryoma of the kidney (Wilms' tumour) have been treated at this institution.

Although the treatment of liver tumours, as judged from a résumé of individual case reports in recent years, has been encouraging, the overall results achieved in significant series have been disappointing and have perhaps fostered a generally hopeless outlook for young patients with such lesions (Donovan and Santulli, 1946; Wangensteen, 1951; Lortat-Jacob and Robert, 1952; Quattlebaum, 1953; Brunschwig, 1953; Pack and Baker, 1953; Lorimer, 1955; Clatworthy and Boles, 1956). In the series from Babies' Hospital in New York City analysed by Andersen (1951) there was only one long-term survivor in 12 cases occurring over a 15-year period. This patient remained well over a six-year follow-up period after excision of the left lobe of the liver had been performed for a mesenchymoma. Gross, in a review at the Boston Children's Hospital, reports two apparent cures out of 18 such cases. One of these received radiotherapy for multiple haemangiomas and has been in excellent health for seven years thereafter; the second has been well over a 10-year period after having a wedge resection of a small haemartoma.

Safe techniques for the resection of the left lobe of the liver have been available for many years, and there are numerous reported successful cases of this procedure applied to removal of neoplasms confined to this lobe. Most of these were performed on adult patients, but a number were in children. More recently the technique for total resection of the right lobe of the liver was evolved, whereby the dangers of haemorrhage, air embolism, bile peritonitis and subsequent liver failure are minimized (Wangensteen, 1951; Lortat-Jacob and Robert, 1952; Brunschwig, 1953; Pack and Baker, 1953; Quattlebaum, 1953; Lorimer, 1955). The application of one or the other of these procedures should permit the surgical excision of most liver tumours which are not centrally placed or diffuse or multicentric lesions.

Diagnosis

The vast majority of primary neoplasms of the liver produce symptoms in the first two years of life. Only two of the 15 cases in this series had the onset of symptoms after 2 years of age, and in three instances the clinical manifestations were present in the neonatal period.

Abdominal enlargement due to a palpable abdominal mass is by far the most common presenting complaint. The distribution of these tumours in the liver, and hence the location of the mass, seems to follow the distribution of the liver mass. Of these 15 tumours, nine were in the right lobe, three in the left and two were situated centrally. One was diffuse. In most instances the mass was in the right upper quadrant, and less often in the mid-epigastrium. The mass moves with respirations. Its characteristics on palpation vary considerably, but most tumours are hard and rounded and inseparable from the liver edge. Transillumination is a useful tool in diagnosis since a liver tumour which transilluminates is almost certainly a large lymphangioma.

Other clinical manifestations observed in this

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

series include anorexia, fever, weight loss and rarely jaundice. This latter sign was observed in only a single case in this series, a 14-year-old girl who died from a liver cell carcinoma associated with post-necrotic cirrhosis. In a single instance, heart failure in a newborn infant progressed to death at 8 weeks, with the pathological findings of diffuse haemangiomas in the liver, skin and pancreas, as has been previously described by Winters, Robinson and Bates (1954) and by Levick and Rubie (1953).

Roentgenological studies are useful in distinguishing hepatic tumours from embryomas of the kidney and neuroblastomas. An intravenous pyelogram is particularly helpful. The kidneys function normally and are usually in normal position in right-sided tumours, although the pelvis and calices may be compressed. Distortion of the pelvis and calices, as seen with a Wilms' tumour, is not present, nor is lateral displacement of the kidney, as with a neuroblastoma, common. The mottled calcification so characteristic of neuroblastoma was not observed, although calcification has been described in some liver tumours. Barium studies of the gastro-intestinal tract show displacement of these viscera away from the tumour as one would expect. Downward displacement of the duodenum and hepatic flexure of the colon is seen with neoplasms of the right lobe, in contrast to the forward or medial displacement usually seen with a renal embryoma or neuroblastoma.

Laboratory tests have been of little diagnostic value in these cases. Liver function studies were all essentially normal except in the case of the child with diffuse post-necrotic cirrhosis. Abnormalities in the liver function tests should lead one to question the diagnosis of primary liver tumour. For example, a diagnostic error was made in a newborn infant, admitted at 2 days of age with jaundice and a large epigastric mass. The jaundice persisted as well as other laboratory evidence of disturbed liver function. At operation at 3 weeks of age the mass proved to be a hard, nodular, grey-white 'tumour' occupying the left lobe. Resection of the left lobe was performed and the child recovered without difficulty. However, on microscopical examination this proved to be a large cirrhotic nodule possibly associated with post-intrauterine hepatitis, with marked fibrous tissue proliferation, replacing the normal architecture of the hepatic tissue. The hepatic cells were completely or partially destroyed and showed irregular arrangement. The bile ducts appeared to be increased. It is interesting that the jaundice disappeared within a month after operation and the infant has been perfectly well over a subsequent eight-month period.

Classification

The wide variety of gross and microscopical characteristics of primary liver tumours and the relatively small number of such cases collected at any one institution have made the adoption of a uniform classification difficult (Warvi, 1944; Edmondson, 1956). To add to the problem is the fact that the clinical behaviour is not always correlated with the microscopical appearance, so that a classification based on the pathological data alone appears to be unsatisfactory. For practical reasons it therefore seems appropriate to group these tumours in three broad categories:

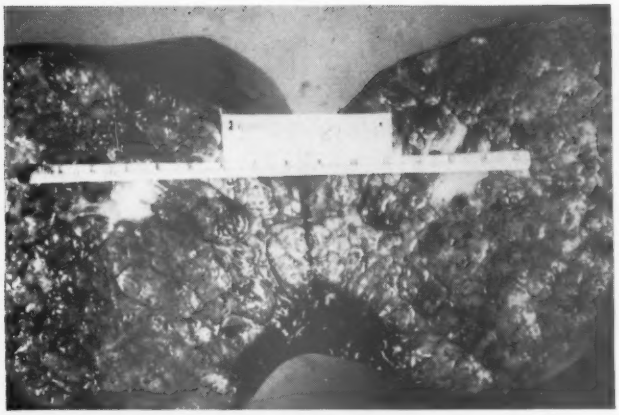
1. **Tumours of Hepatic Cell Origin.** This group is made up of all tumours derived from entodermal cells and includes hepatomas, cholangiomas and the cholangiohepatomas. There were no adenomas in this series and the hepatomas have invariably behaved as malignant lesions, although the histological appearance may suggest benignity (Fig. 1a and b).

2. **Tumours of Supporting Structures.** This group comprises those tumours of mesodermal origin including fibromas, haemangiomas, lymphangiomas, fibroangiomas and mesenchymomas. Such neoplasms may be benign, as are most of those in this series, or malignant.

3. **Mixed Tumours and Teratomas.** Such tumours contain cells derived from more than one germ layer. Osteoid tissue, for example, may be seen in liver cell tumours. Teratomas are distinctly rare (Fig. 2).

In this series hepatoma was the most common tumour encountered, occurring in 10 cases. Five were in the right lobe, two in the left and two were centrally positioned. In eight cases symptoms developed in the first two years of life, and the ninth patient had his initial symptoms at 2 years 11 months of age. None of these nine patients had associated cirrhosis so commonly found in adult cases. However, as already mentioned, the tenth case occurred in a 14-year-old girl with post-necrotic cirrhosis of the liver. There were no instances of adenomas or exclusively bile duct tumours among these cases and only a single case of histologically benign cholangiohepatoma occurring in the right lobe of a 10-week-old infant.

Among the tumours of supporting tissue origin were one diffuse haemangioma, two lymphangiomas and one fibroangioma. There were no mesenchymomas, mixed tumours or teratomas. Both



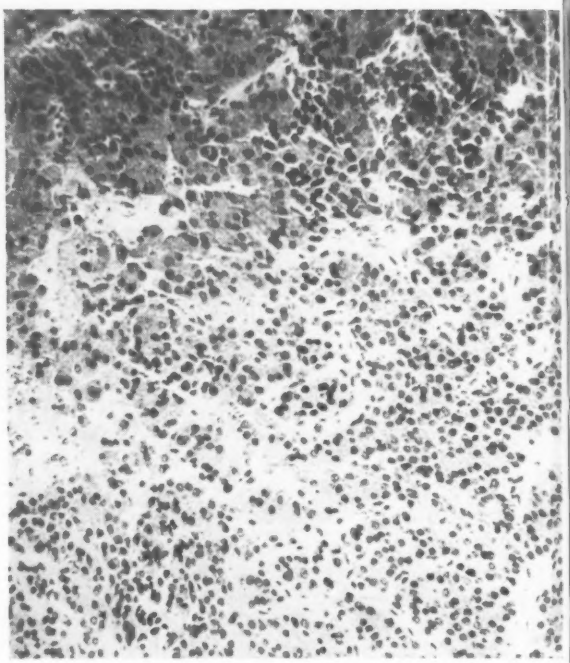


FIG. 1 (a).—Gross and microscopical appearances of a well-differentiated hepatoma of left lobe of liver successfully excised from a 15-month-old infant who subsequently died of undifferentiated hepatic and pulmonary metastases seven months after original resection.

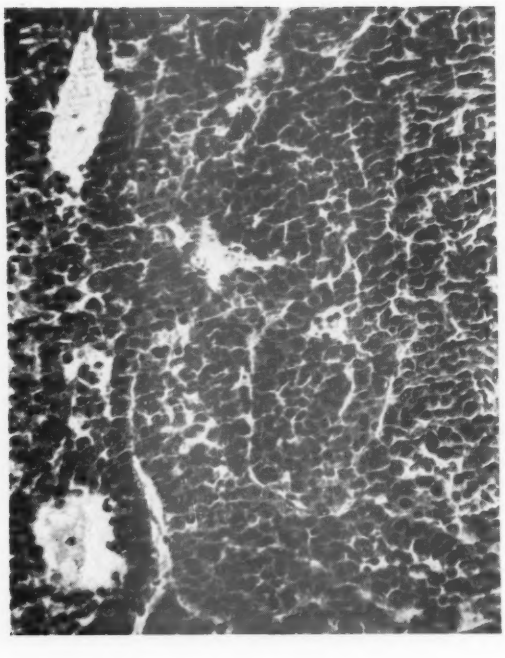


FIG. 1 (b).—Gross and microscopical appearances of a very rapidly growing anaplastic hepatoma of left lobe of liver easily resected with wide margin of normal liver substance in a 2-year-old infant who succumbed to multiple recurrences in right lobe of liver within five months.

FIG. 2.—Gross and microscopical appearances of mixed tumour of liver in a young child; it contained highly undifferentiated hepatoma as well as areas of osteoid tissue.

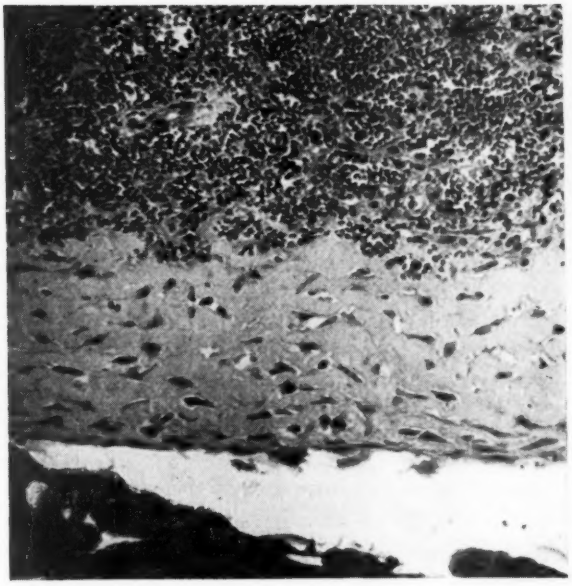


FIG 3.—Gross and microscopical appearances of a huge rapidly gro ng lymphangioma involving entire right lobe of liver which was suc ssfully excised from a 9-month-old infant who is well nine months later.

lymphangiomas were found in the right lobe of infants, one 4½ months and the other 9 months of age (Fig. 3). The patient with diffuse haemangiomatosis, already noted, had symptoms at birth. The liver of this patient had numerous small capillary haemangiomas scattered diffusely throughout all portions of the liver parenchyma. The single case of fibroangioma was a newborn infant with the neoplasm originating in the left lobe.

There is a strikingly similar gross appearance of many of these tumours, so that differentiation by this means alone is often quite unreliable. Similarly, the differentiation microscopically of benign and malignant liver cell tumours is occasionally virtually impossible. In one of the hepatomas in this series the cytology and architecture were most suggestive of a benign neoplasm, but the presence of metastases established the malignant nature of the tumour.

Treatment

Effective treatment of primary hepatic neoplasms is at present limited almost entirely to surgical resection. Radiotherapy may be of value in haemangiomas, as suggested by Gross, and in one of our cases of inoperable hepatoma radiotherapy resulted in definite regression in size of the tumour mass. Systemic chemotherapy has not been of value to date.

In tumours limited to either the right or left lobe, surgical removal by total right or left lobectomy is a practical procedure. Such procedures take advantage of the anatomical division of the organ into right and left lobes, each with a largely separate blood supply from the hepatic artery and portal vein. Control of the blood supply and the bile duct system at the hilum of the liver plus similar control of the hepatic veins draining into the inferior vena cava make possible such resections without excessive risk from haemorrhage, air embolism, or bile peritonitis.

In such a procedure for a tumour involving the right lobe the diagnosis is confirmed and operability determined through an abdominal incision. If resection appears possible the abdominal incision is joined or extended by an incision into the right chest through the seventh or eighth intercostal space, and the right diaphragm is divided down to the vena cava. Umbilical tapes are then placed around the inferior vena cava just below the right atrium and above the renal veins. The hilar structures are freed and the appropriate branches of the hepatic artery, portal vein and hepatic duct are carefully identified, ligated and divided. The short hepatic veins from the right lobe to the vena cava are next ligated and divided. This is the most dangerous part of the procedure since extension of the tumour into this area may not be appreciated until this part of the dissection is under way, and if such extension is encountered there is a considerable risk of haemorrhage or air embolism. The previously placed tapes on the vena cava and control of the hilar structures permit control of such a situation. Following this the liver is transected to the right of the falciform ligament down to the vena cava. During the actual transection the hilar structures are cross-clamped with a Pott's clamp. Interruption of the blood supply by this means can safely be tolerated by the liver for about 15 minutes, and probably longer with the controlled moderate hypothermia (90°-92° F.) customarily employed in these cases. All visible blood vessels and bile ducts are ligated as the dissection proceeds. If the gallbladder is not involved, it may be peeled out of its bed before the transection and used after removal of the lobe for retrograde injection of a methylene blue solution. By this means additional bile ducts can be visualized and ligated. The falciform ligament and posterior peritoneum are used to reperitonealize the raw surface. If this is not sufficient, a layer of compressed Ivalon may be sutured in place to cover the remaining raw area. Penrose drains are placed to drain the right subdiaphragmatic space so that a localized collection of bile or a bile peritonitis will not occur.

The left lobe can be mobilized more easily than the right and this can ordinarily be done through an upper abdominal incision by dividing the peritoneal attachment to the diaphragm and the falciform ligament. It is quite easy to place a row of interlocking mattress sutures just to the left of the falciform ligament and resect the left lobe. It has not been found necessary to perform a hilar dissection or to occlude the hilar structures during this procedure. Again, however, reperitonealization of the raw surface and drainage are important steps.

Results

There have been no long-term survivors in the 10 patients with hepatoma. In one, the diagnosis was not made until post-mortem examination and no treatment was given. In two, only exploration and biopsy were performed, and both died within three months. In two others, exploration and biopsy were followed by radiotherapy. The tumour mass strikingly decreased in size in one of these, but none the less the patient lived only six months after completion of the treatment. The other lived only four months after therapy.

Right lobectomy was performed in four patients and there were three early deaths. One of these

patients died from operative haemorrhage, and a second from haemorrhage and air embolism. A third unfortunate death resulted from staphylococcal peritonitis and septicaemia two weeks after operation and at autopsy no tumour was found. All three deaths must be considered preventable. The first two cases were in retrospect inoperable because of tumour invasion across the midline posteriorly in the area of the hepatic veins. The third death presumably followed contamination in the operating room or via the drain site. The fourth patient who had a resection of the right lobe died at home two and a half months after operation following a brief acute illness suggestive of intestinal obstruction. The patient was not returned to the hospital during this illness and no autopsy was performed. A left lobectomy was performed in the final patient, and he died with massive metastases in the right lobe seven months after resection. This last patient had been known by his parents to have an abdominal lump since 3 months of age, but no treatment was sought until 15 months later at which time a huge tumour in the left lobe was found.

The single patient with a cholangio-hepatoma had a resection of the right lobe of the liver at 10 weeks of age (Fig. 4). He is living and well 12 months later with no evidence of recurrence.

Both patients with giant lymphangiomas had tumours occupying almost all of the right lobe. Resections of the right lobe were done at 5 and 9 months, and both patients are in good health

FIG. 4.—A 10-week-old infant one week after total right hepatectomy for cholangio-hepatoma.

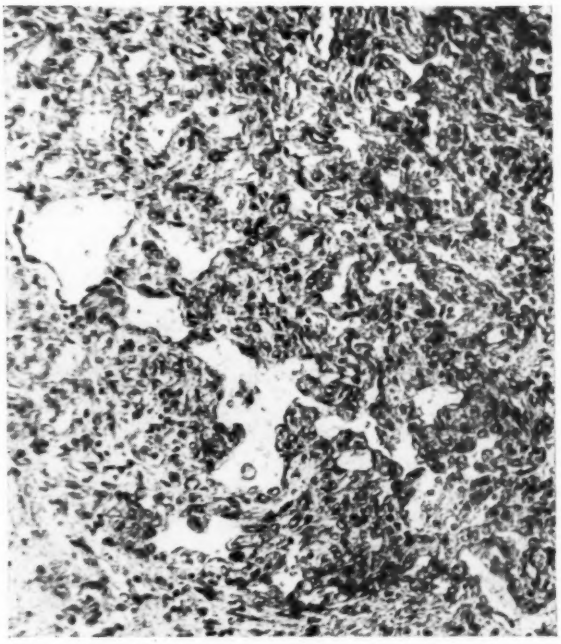


FIG. 5.—Microscopical appearance of liver removed at autopsy from an 8-week-old infant with multiple diffuse haemangiomas who had been under treatment since birth for 'heart failure'.

six and a half years and nine months later. The infant with a fibroangioma of the left lobe had a left hepatectomy at 3 weeks of age, and is well 14 months later.

None of the long-term survivors after resection of the right or left lobe shows any evidence of impairment of liver function. Although in all cases there was a plateau in weight gain for a few weeks after operation, subsequent growth and development patterns have been entirely normal.

The patient with diffuse haemangiomas of the liver, as well as of the pancreas and skin, was treated for heart failure from birth and died at 8 weeks of age. The diagnosis was made from the autopsy findings (Fig. 5).

Discussion

Primary liver tumours are not rare paediatric problems. Without treatment the prognosis is poor in both the malignant and benign varieties, as indicated by the larger reported series (Andersen, 1951; Gross, 1953; Lee, Newstedt and Siddall, 1956). With adequate surgical resection the prognosis in cases of benign tumours is good, and after such treatment normal growth and freedom from liver impairment may be expected. The outlook for patients with malignant tumours, even after operation, has thus far been poor, but with the

development of more adequate techniques in achieving wide resections there is reason to believe that success may be achieved. One remarkable exception is the case reported by Lee *et al.* (1956) of an infant with a huge hepatoma confirmed by biopsy. No treatment was given but spontaneous regression occurred and the child was reported in good health 10 years later.

Establishing a clinical diagnosis of a primary liver tumour is ordinarily not difficult; however, the differentiation of a benign from a malignant tumour clinically or at operation may be quite impossible. Two such dilemmas occurred in this series. Since surgical excision currently affords the only chance of eradicating such lesions, it is our opinion that in the absence of distant metastases isolated lesions should be removed.

The techniques of resection of either the right or the left lobe are sufficiently well developed to permit their application with a reasonable assurance of success. The major problems are haemorrhage, air embolism and bile peritonitis. An anatomical technique with control of the afferent and efferent blood supply, controlled hypothermia, reperitonealization of the cut surface and adequate drainage are methods which contribute to the success of these procedures.

Summary

The majority of primary liver tumours which present as clinical problems in children are malignant and occur in the first two years of life. Such tumours develop in a normal liver, and are not superimposed on a cirrhotic process as in adults.

From the practical standpoint these neoplasms can be classified as (1) tumours derived from liver cells, (2) tumours derived from supporting cells, and (3) mixed tumours. Those derived from liver cells are malignant in the vast majority of cases, although the microscopical picture of some is quite benign.

The solid tumours of the liver should be treated in a uniform manner, adequate surgical excision through normal liver tissues being the best available procedure.

A surgical technique based on sound anatomical principles and planned to minimize the risks of haemorrhage, air embolism and bile peritonitis makes removal of these tumours by a resection of either the right or left hepatic lobes a logical and practical procedure.

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RESULTS WITH ABDOMINAL RESECTION IN HIRSCHSPRUNG'S DISEASE*

BY

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For six years we have been practising abdominal resection for Hirschsprung's disease. The method is also known as segmental resection, anterior resection or State operation.

The operative technique has, apart from certain small alterations, always remained the same. In the application of this procedure certain aspects have been revealed which are important for the theoretical interpretation of the disease and also have practical significance, no matter which method is considered the best.

We need not go into the fundamental work of Swenson and Bodian. Swenson himself presented his views in detail five years ago at the first meeting of the British Association of Paediatric Surgeons, and Ehrenpreis (1955) lectured on Hirschsprung's disease in the newborn infant at the same time.

In 1951 and 1952 we operated on our first cases according to Swenson's method (Swenson and Bill, 1948) and it occurred to us at that time that a dissection of the rectum might possibly lead to a disturbance of sexual potency, to incontinence and to disturbances in evacuation of the bladder. For this reason we switched to the State operation in 1953. Meanwhile it has been proved that this anxiety was unfounded. Swenson (1957) reported that eight patients who had been treated surgically had become fathers and that six others, all over 20, had no disturbance of potency. Wyllie (1957) reported that, among the large number of patients from the Great Ormond Street Hospital, hardly any lasting disturbances of bladder function had been observed. Incontinence of faeces usually disappears after some time. Only Hiatt (1958*b*) reports lasting troubles in 16%. Injury to the pelvic vegetative nerves can however only be avoided if the dissection of the rectum is made close to the wall of the bowel. As Swenson himself says, this part of the operation is time-consuming and difficult. But this difficulty disappears when the intra-abdominal method is used. Thus it is simpler and can easily be withstood by weak infants. Only the simplicity of this procedure therefore induces us to keep on using it.

Fig. 1 shows that the majority of cases were operated on between the ages of 6 and 12 months.

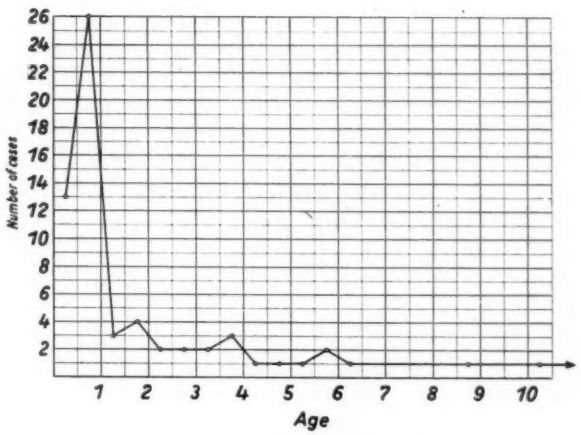


FIG. 1.—Age (yr.) of children at time of operation.

From 1953 to 1958, 67 children were operated on in this way. In 56 cases there was the typical finding of a narrow segment.

In 11 cases there was no narrow segment. These cases belong to the megarectum group. Pathological examination disclosed absence of ganglion cells at the lower portion of the resected bowel.

In 60 of the 67 cases treated surgically the diagnosis was confirmed histologically. In seven cases there was no complete aganglionosis. Besides large nerve trunks occasional ganglion cells were found throughout various sections of the lower end of the specimen. We took these cases to be Hirschsprung's disease also.

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

Operative Technique

In abdominal resection the upper rectum is cut through. The resection either involves the sigmoid alone or more often extends to the splenic flexure. In 1952 State pointed out that in most cases the rectum, although aganglionic, is wide or at least distensible. In dissection of the upper rectum it can very often be seen how the narrow segment becomes somewhat wider in the lower direction. The level of the transection is about 1 cm. below the pelvic peritoneal floor (Fig. 2). This level is still easy to reach from an abdominal incision. The distance of the anastomosis from the anus varies according to the age of the child, and the peritoneal floor is sometimes lower, sometimes a little higher. It is about 6-10 cm. and can always be touched by the finger. The whole sigmoid at least must be removed. The wide lumen and the hypertrophied wall are not suitable for anastomosis. In addition resection of the sigmoid eliminates a reservoir in which faeces can accumulate. When the dilatation extends into the descending colon, we have resected as high as the splenic flexure. Even when the resection is extended to the splenic flexure, both lumina are not usually the same size, but the wall is no longer hypertrophic. Care must be taken in anastomosis to ensure that the surplus of the wide lumen is evenly distributed over the narrow lumen (Fig. 3). In the few Hirschsprung cases which had a wide aganglionic rectum but no narrow segment the problem was reversed. We always perform the anastomosis with an open bowel without clamps. A slight soiling of the operational area cannot always be avoided; breakdown of the suture, infection or peritonitis have never occurred. In a large number of cases the anastomosis remains wide and can only be felt as a fine scar. The colon and rectum eventually attain the same calibre. In other cases a slight sickle-shaped projection exists to one side or all round. Occasionally a moderate or serious stenosis has occurred. Then part of the evacuation pressure is lost. But for the success of the operation it is conditional that the anastomosis is wide.

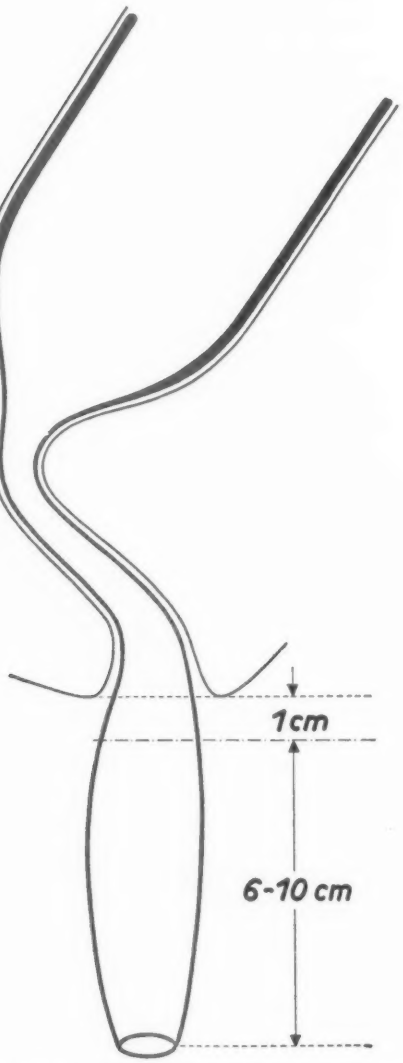


FIG. 2.—Level of transection is situated in upper rectum 1 cm. below pelvic peritoneal floor. Distance from anus varies from 6-10 cm.

Achalasia

In one of the first cases which was operated on in this way five years ago abdominal distension and constipation recurred two years later (Fig. 4). Examination revealed that there was no stenosis of the suture. The remaining rectum had expanded. The ampulla was filled with soft faeces. After a vigorous sphincter dilatation and washouts, evacuation started again and the abdominal dilatation disappeared. This child has had no stool difficulties for three years.

It is very interesting that Thomas (1958) describes the same findings in two cases treated by recto-sigmoidectomy. This observation, which we also made in other children, is important and suggests that in a case of so-called recurrence the cause is a disturbance of anal function, of the evacuation reflex. Probably it is impossible for the sphincter to relax, in other words an achalasia; or, instead of a relaxation, a contraction occurs. This disturbance of co-ordination must already exist before the operation. But as long as there is a narrow segment this disturbance does not appear so clearly, as it is concealed by the narrow segment. It may be

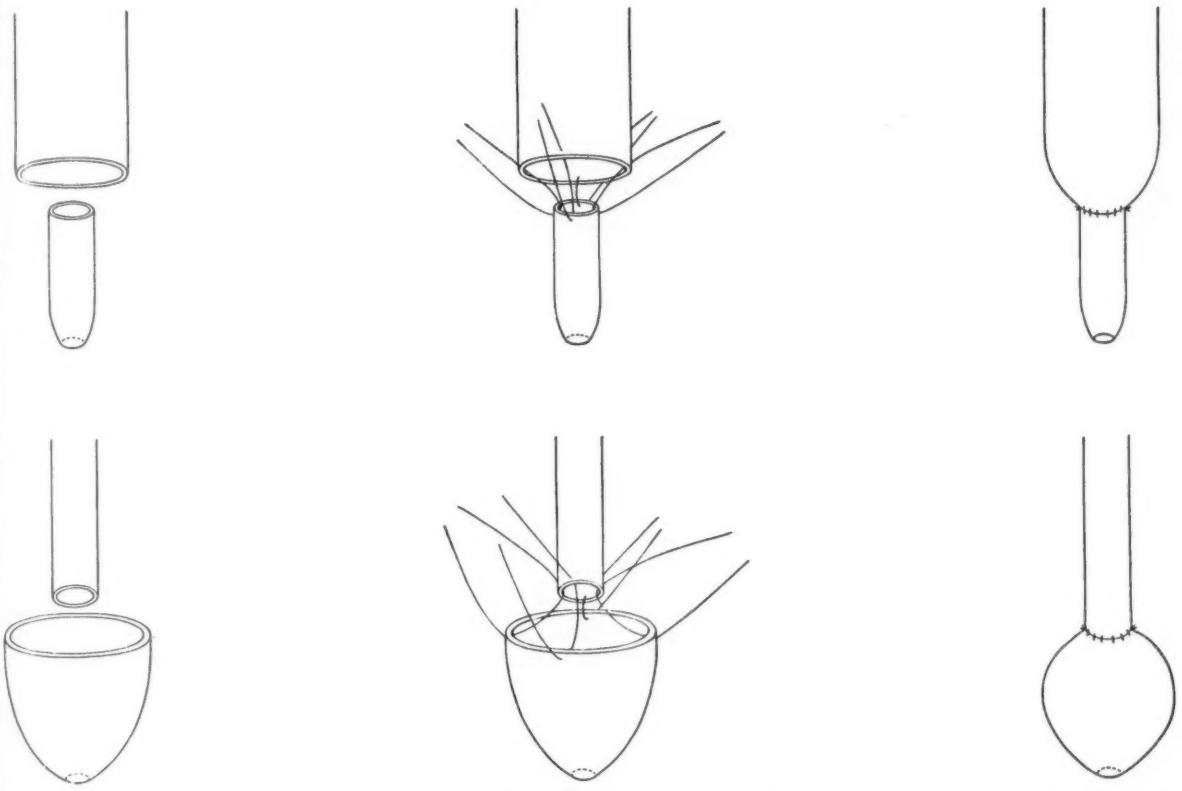


FIG. 3.—Great difference of calibre in common form of Hirschsprung's disease (above), and in megarectum type (below), causes difficulties in anastomosing technique. Surplus of wide lumen must be evenly distributed over narrow lumen.

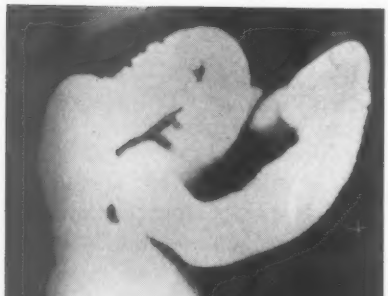
assumed that this disturbance of co-ordination is part of the whole disease and is also an expression of the defect of the parasympathetic nerve system of the pelvis. This theory of achalasia is an old one. In 1934 Hurst proposed to treat Hirschsprung's disease by dilating the sphincter. The result must however have been poor since nothing was known at that time of the importance of the narrow segment. Dilatation causes rupture of muscle fibres. The strong sphincter closure is weakened and evacuation made easier. The weakening of the sphincter is intended to replace the active relaxation which is lacking. With abdominal pressure the weakened sphincter is overcome passively during defaecation. As we must assume that this achalasia exists in every case of Hirschsprung's disease, we dilated the sphincter immediately after every operation. It soon appeared that the desired effect was not permanent in some cases, especially in infants. Apparently the severity of achalasia varies with different cases. The dilatation had to be repeated several times. From later examinations we ascertained that a powerful sphincter closure had often reappeared. Lasting incontinence has never occurred.

Immediate Post-operative Results

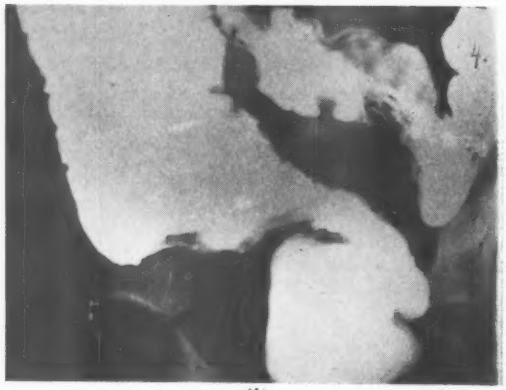
Most children began to empty their bowels one or two days after the operation and no further measures were necessary. Other cases had to be helped from the start with a flatus tube and enema and it was a long time before they could evacuate on their own. The abdomen became again distended. A tube or the finger need be inserted only a few centimetres and gas and stool are evacuated and the abdomen collapses. Here we are dealing mainly with infants. The colon appears to have no power at all to propel stool in such cases and the slack abdominal walls cannot effect defaecation. But it also happens that, after easy emptying at first, difficulties arise because the anastomosis has a tendency to narrow. These difficulties can be surmounted if daily bouginage with very thick bougies is begun soon after the operation. Thus one can avoid stenosis of the suture and at the same time maintain the effect of sphincter dilatation.

Later Results

Six of the children on whom we operated died. All were infants. Five deaths had no immediate



(*a*)



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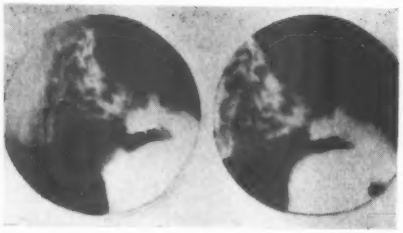


(*c*)

(*d*)

(*e*)

FIG. 4.—8-year-old girl with signs typical of Hirschsprung's disease (*a-c*) operated on five years ago; recurrence of symptoms two years after operation (*d*, *e*). Considerable dilatation of large bowel. Remaining rectum wide.

connexion with the operation. One of the first children died of peritonitis; perforation of the bowel had been caused by bouginage. Another child was found dead in bed at home. The third child died during an operation on an incisional hernia in another hospital. The next died also at home, probably as a result of ileus. Another, in whom a colostomy had been done in the newborn period, died during closure of the colostomy. Only one child died two days after the resection, a 6-month-old infant with mongolism.

We have examined many of the children since the operation or received written reports from their parents. Children who have been operated on this year have not been taken into consideration. We have only been able to examine a certain number radiographically. We think, however, that they will suffice to give a picture of the results (Figs. 5-7).

Thirty-seven of the 67 children have been completely relieved of their symptoms (Table 1), they

TABLE 1
RESULTS OF ABDOMINAL RESECTION IN 67 CHILDREN WITH HIRSCHSPRUNG'S DISEASE

Year	No. of Cases	Laxative, Enema, Abdominal Distension			Died	No Response
		None	Sometimes	Always		
1953-58	67	37	11	9	6	4

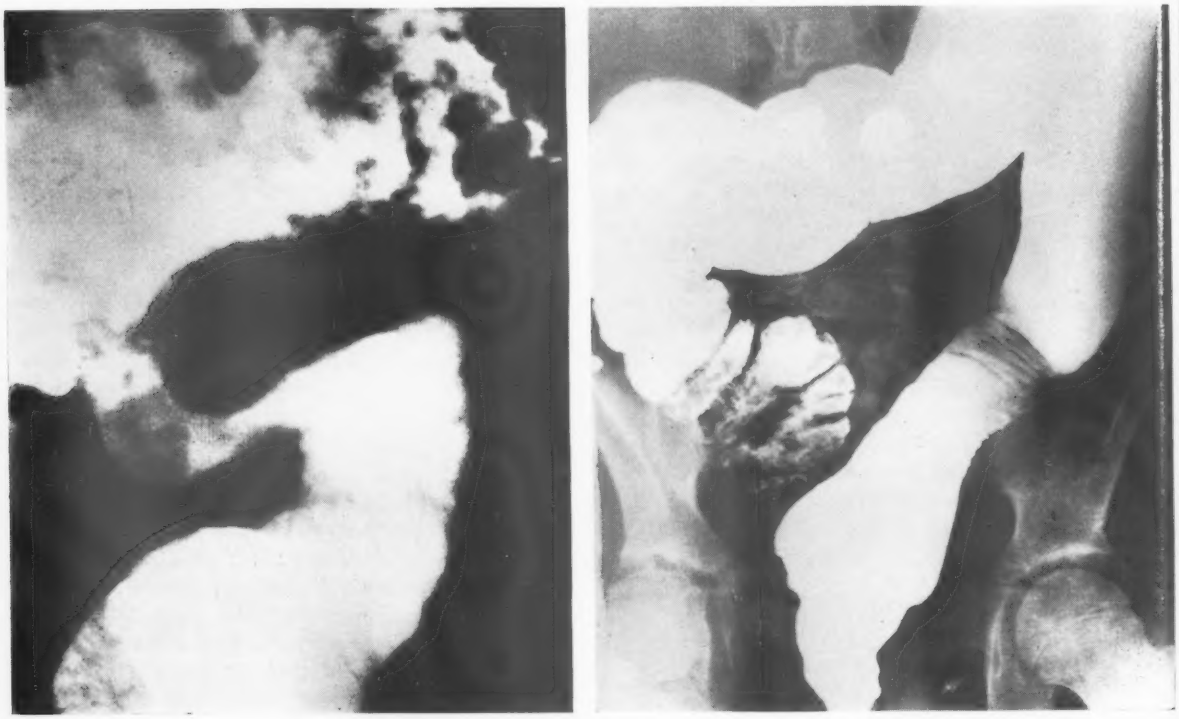
need neither enema nor laxatives, they have no abdominal distension and have bowel movements daily. Nine results were poor. The 11 children who are listed in the second group need laxatives and enema occasionally*. A few sometimes show slight abdominal distension. Of course it would still be possible to record a few of these children as good results. Sixteen children empty the bowels once a day; the remaining children do this two or three times daily. Only in some of the cases are the motions solid; usually they are loose. With some children, who had initial difficulties in evacuation, the results have improved with the course of time, whilst others deteriorated some months or even as much as two years after the operation. It may be assumed that from approximately the third year after the operation the results remain steady. It is remarkable that even cases which are clinically completely free of symptoms and seem to be cured still show a certain dilatation of the colon. Wyllie (1957) made the same observation in his children after rectosigmoidectomy. Usually one can still detect the site of anastomosis fairly clearly. The rectum is distended. Cases with noticeable dilatation can also be free of symptoms. The distended bowel is in the stage of compensation. This stage of compensation can last for years and is then practically equivalent to a cure, although the latent possibility of a deterioration or a slow retention of stool may exist in some cases.

* Ten of these 20 cases have subsequently become symptom free.

Discussion

Not all cases are equally suitable for abdominal resection. The narrow segment can be situated deep in the rectum, and then anastomosis becomes difficult or impossible; or the narrow segment extends deep into the rectum. In the commonest forms of Hirschsprung's disease, however, when the narrow segment is situated in the rectosigmoid, abdominal resection can achieve good results. The most important thing for the success of the operation is that no obstacles to emptying should remain. No anastomotic stenosis must exist, nor any hindrance to evacuation because of a closure of the anus or a diminished ability to open. None of the narrow segment must be left, but most of the aganglionic rectum must remain. Because on radiological and rectal examination after the operation the rectum is wide, or at least distensible, we cannot believe that the remaining rectum is the cause of any failure. It is not a passive hindrance as is the narrow segment. If evacuation troubles occur, then the sphincter is responsible. Therefore, from this point of view also, a second operation is not necessary.

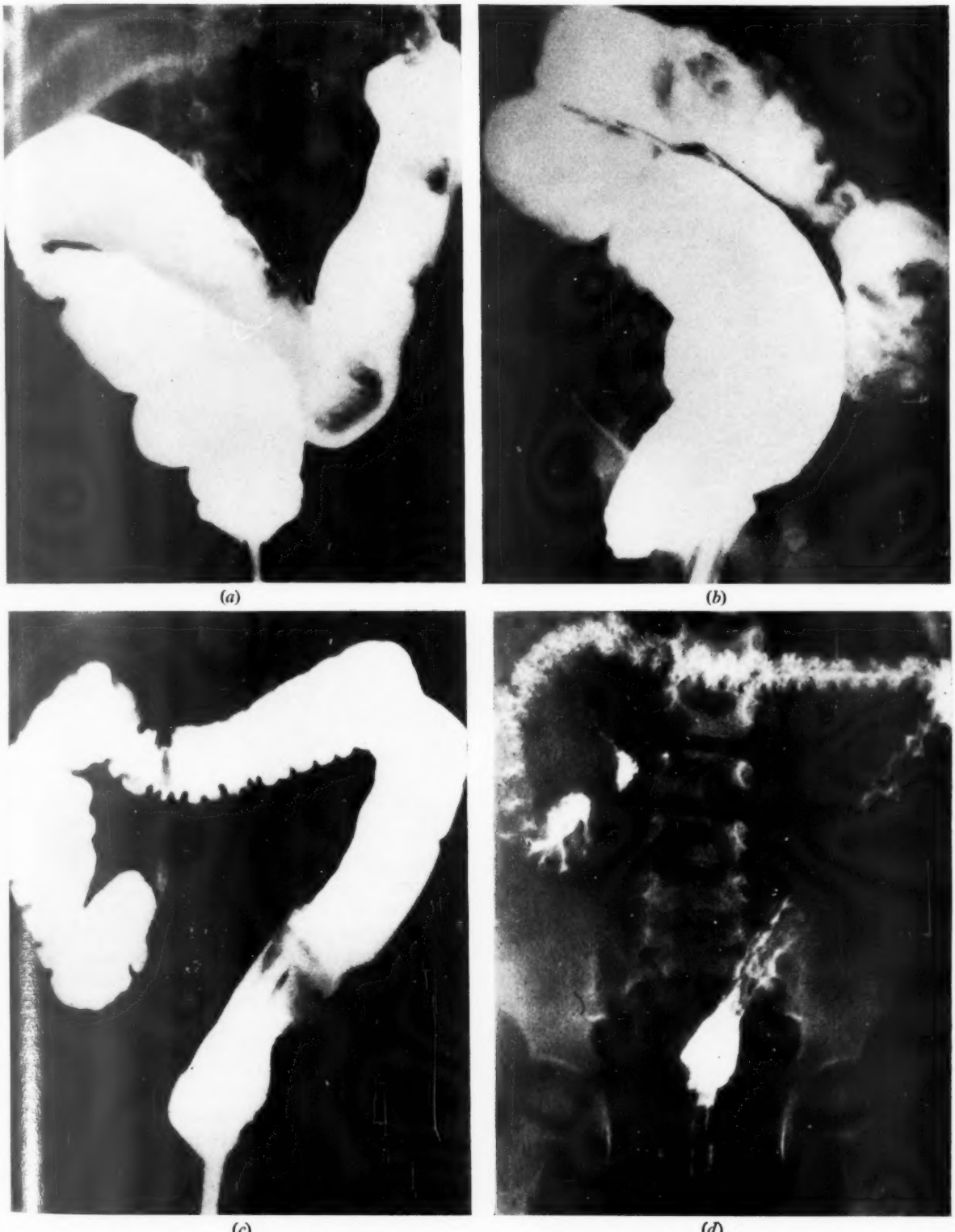
In rectosigmoidectomy, transitory disturbances of continence occasionally appear as the reports of Swenson (1957), Hiatt (1958a), Wyllie (1957) and others show. This perhaps leads to the conclusion that with dissection of the rectum the achalasia of the sphincter is removed at the same time. A transitory disturbance of continence seems especially favourable with regard to final success. If the bowel can empty itself immediately without any hindrance in the post-operative phase, it has the opportunity to return to normal calibre and is not open to the danger of renewed dilatation. We know that it can return to normal calibre from the colostomy alone. If the sphincter then gradually regains its ability to close, the colon has time to adapt itself functionally to the sphincter. The question of a lasting weakening of the sphincter seems to be the problem with abdominal resection. The function of the sphincter must be permanently weakened so far that continence is just retained. A single dilatation of the sphincter can effect this. But the sphincter has a tendency to regain its ability to close tightly. If that happens, the dilatation must be repeated and it is necessary to continue treatment for some time with



(*a*) (*b*)

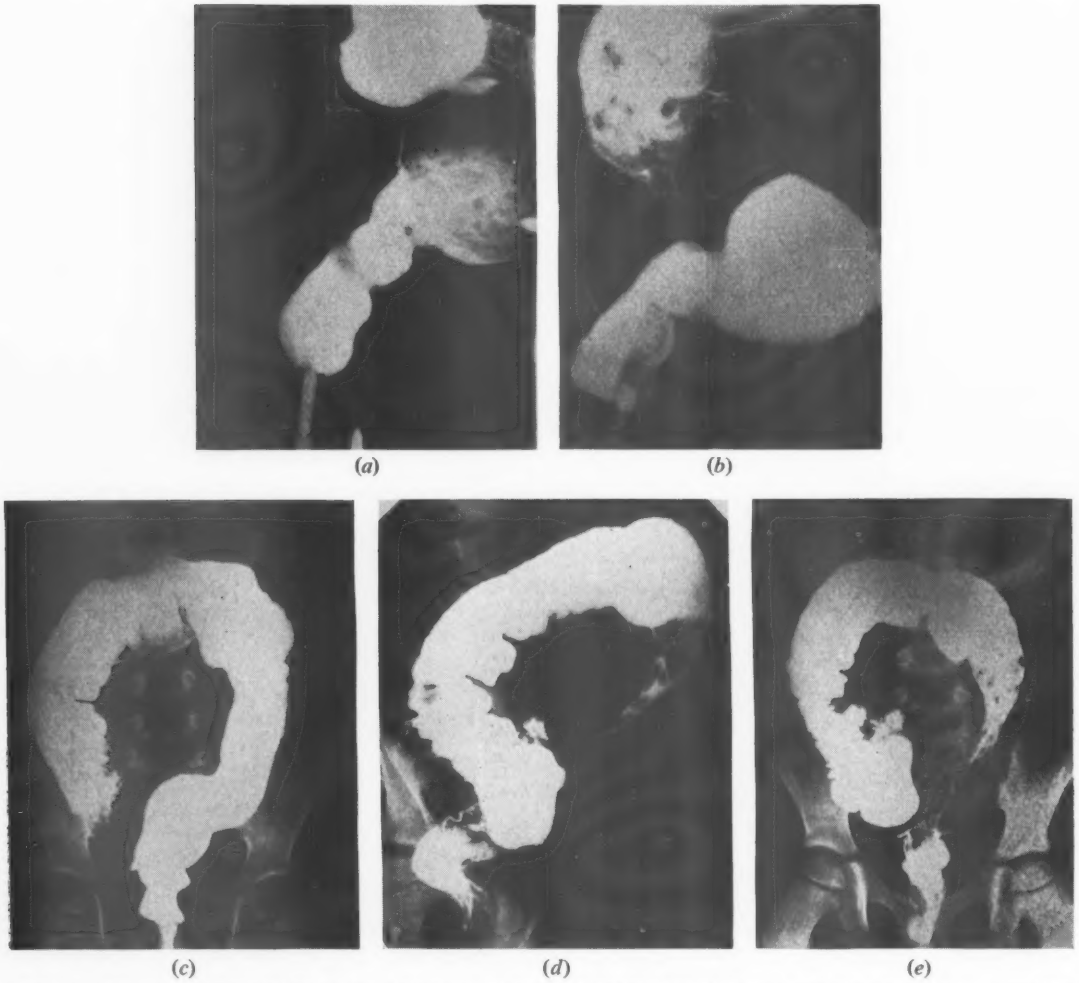
(*c*)

FIG. 5.—X-ray (*a*) before, and (*b*, *c*) six months after operation on a 19-year-old boy. Large bowel completely filled and showing good emptying. Operation performed five years ago. Full relief of symptoms.



(*a*) (*b*) (*c*) (*d*)

FIG. 6.—(*a*, *b*) X-rays of an infant with megarectum type of Hirschsprung's disease; (*c*, *d*) follow-up 12 months after operation. Level of anastomosis can be seen. Good emptying.



(*a*) (*b*) (*c*) (*d*) (*e*)

FIG. 7.—5-year-old boy operated on at 6 months of age. X-rays (*a*, *b*) before, and (*c-e*) four years after operation. Ascending and transverse colon a little more distensible than normal. Satisfactory evacuation of descending colon. Slight diverticula in region of anastomosis. Full relief of symptoms.

thick bougies. The reason why deterioration has been noticed in some of our patients since our 1958 publication (Rehbein, 1958) is to be found in the fact that this systematic treatment, the necessity for which Wyllie (1957) has also pointed out, has not been sufficiently carried out. Up to now this treatment has given us good results in children in whom the earlier results had deteriorated. We may therefore assume that for the other children in the second and third groups of the Table there is still the prospect of a cure. The passage from a good result to renewed constipation can be insidious and unnoticed. If, for example, the emptying of stool no longer takes place daily, or a slight abdominal distension is observed, or even if stool and gas have to be evacuated with the tube from time to time, that is a sign that the bowel is threatening to enter the stage of decompensation. It is necessary to act on these signs in good time.

One must as a rule seek the cause of evacuation difficulties in the anastomosis or in the anus. Only once were we induced to remove the dilated descending colon in an infant during a second operation three months after resection of the sigmoid. The result was good (Fig. 8). In many cases we have resected the colon to the splenic flexure at the beginning. But we are not sure whether that is always necessary. If evacuation cannot take place unhindered, it is of no use however high the resection is.

The treatment of Hirschsprung's disease is most problematical in infancy, but most children are treated at that age. Swenson has for some years limited himself to making a colostomy in infants and

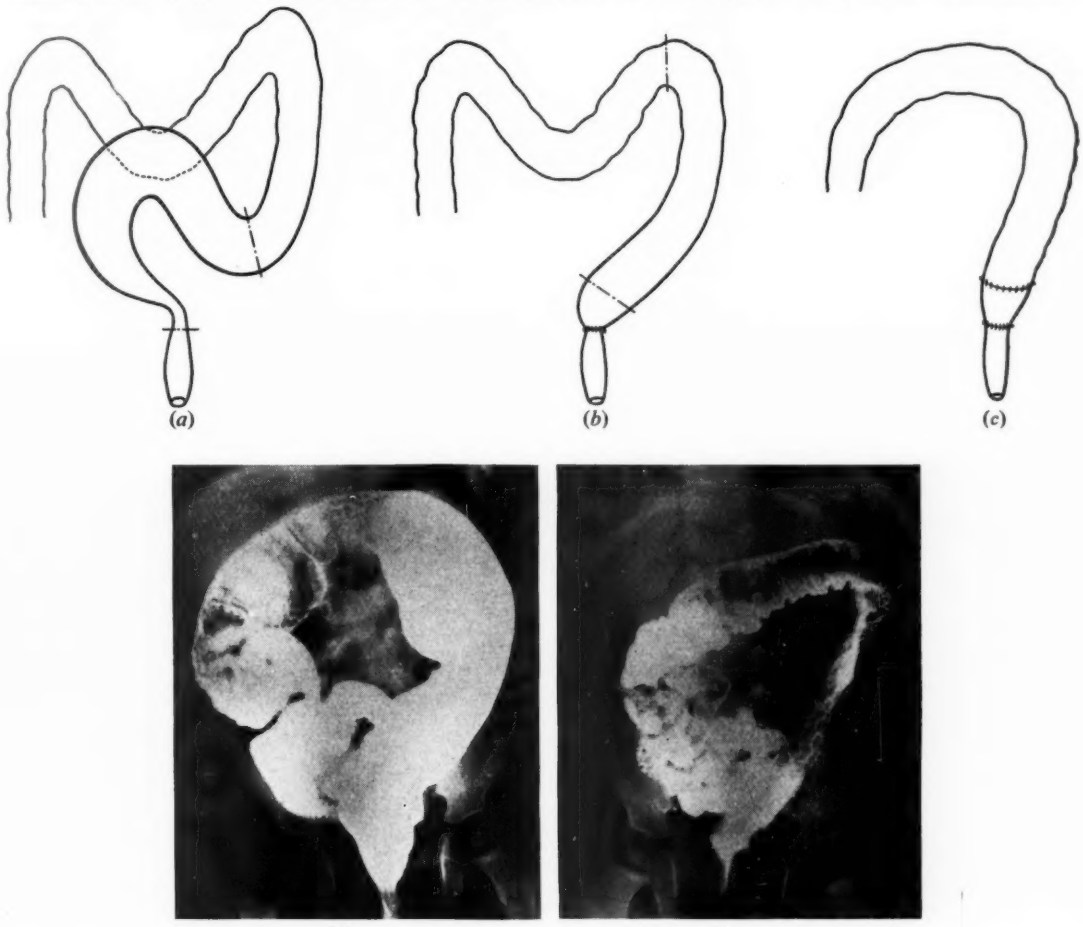


FIG. 8.—20-month-old boy operated on twice in period of three months. (*a-c*) diagrams of procedure; (*d, e*) X-rays seven months after last operation. Free of symptoms.

delaying the resection until the children are 12-18 months old. We have always performed the resection in the first year, and only with ileus in the first weeks of life have we done a colostomy. The future must show which is the better way. But it is the general opinion that operative treatment must take place in infancy. On the other hand, by this early treatment we also receive the serious cases which would have died earlier. So it must be explained that post-operative treatment is more necessary than in older children. In addition these children do not know normal bowel evacuation and do not use abdominal pressure. Stool simply remains in the terminal bowel. One can only treat with the tube, enema, bouginage and laxatives until they have learned spontaneous emptying. If the children are a little older they can help themselves and one can execute bowel training.

We have intentionally indicated the difficulties connected with the application of abdominal resection. The procedure is smaller and simpler than rectosigmoidectomy but demands intensive post-operative supervision of the child to a higher degree. It is certainly too early for a final picture to be drawn up. The arguments which are raised against the method are not justified in so far as failure lies not in the method but probably in insufficient post-operative treatment. The recurrent necessity for this treatment is a disadvantage compared with rectosigmoidectomy. These difficulties are not insuperable and therefore we see at the moment no reason to depart from this method.

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A NEW OPERATION FOR THE TREATMENT OF HIRSCHSPRUNG'S DISEASE*

BY

BERNARD DUHAMEL

From Paris

The excision of the aganglionic segment of the recto-sigmoid colon proposed by Swenson is the logical outcome of the new conception of the aetiology of Hirschsprung's disease and I do not think it necessary to discuss it here any further.

The operation which I shall describe constitutes but a technical variance of Swenson's operation and is not a new method; it has also some other applications apart from the treatment of congenital megacolon. The object of this operation is to exclude and not to resect the malformed rectum and all dissection of the pelvis is avoided. The functionally healthy proximal colon is brought down to the margin of the anus in a plane of anatomical cleavage, and thus the nervous system of the bladder and neuro-muscular apparatus of the sphincters are preserved *in toto*. A wide anastomosis between the colon and the excluded rectum is performed and, by preserving the rectum, an important area of reflex activity is preserved.

Hirschsprung's disease is a serious condition but it is not a malignant disease in the usual sense of the term; therefore an operation designed to remedy the condition should not be of excessive severity, and there should be no risk that one functional anomaly (urinary incontinence or impotence) will be substituted for another. Swenson's operation is a delicate and difficult intervention which only gives excellent results if it is carried out by a very competent surgeon operating on children of a certain age.

Since the characteristic deficiency of ganglia in Hirschsprung's disease nearly always affects the whole of the rectum down to the level of the internal sphincter, an extensive resection of the rectum, which is associated with considerable shock, especially in the newly born, must be performed in order to obtain a satisfactory surgical result.

Dissection of the rectum can be carried out close to the muscular layer since one is not dealing with a malignant condition; it is nevertheless possible to traumatize the pelvic nervous plexus supplying the bladder or the genitals. Complete ablation of the mucous membranes of the rectum or of its nerve supply will interfere with rectal sensation which is indispensable to the perfect function of the sphincters.

Whatever the extent of the resection of the rectum, it is always incomplete inferiorly as it is essential to preserve the rectal sphincter. Thus an unsatisfactory result is common and relapses are possible.

The end-to-end anastomosis is liable to separate either partially or completely if the vitality of the pulled-down colon is endangered or if the operative technique is incorrect. In a certain number of cases serious complications, such as peritonitis, pelvic abscess or fistula, may result.

Lastly the anastomosis can (and this is a most frequent complication) become stenosed and may at times become completely occluded.

It is because of these complications, which cannot be avoided in spite of the technical modifications described by some authors, that some surgeons have rejected Swenson's operation and returned to abdominal resection followed by dilatation of the sphincter. This is probably a retrograde step since one knows that in most cases the lower part of the rectum and the internal sphincter are themselves malformed. The same objections could be raised against those who have proposed a recto-sigmoid-myotomy inspired by the operation of Heller since they do not prolong their extramucous incision beyond the level of the pouch of Douglas, and have to complete the operation by carrying out an anal dilatation.

In a recent book (Duhamel, 1957) I have described and illustrated in detail my surgical technique and I shall therefore mention here only the essential steps.

Operative Procedure

Abdominal Approach. (1) The rectum is divided, closed and buried at the level of the pouch of Douglas, as in Hartman's operation.

(2) After resection of the narrowed recto-sigmoidal zone and that of the adjoining megacolic

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

segment, which is usually toneless and full of faecoliths, the proximal colon is mobilized (care being taken to preserve its blood supply) and must be long enough to allow its being brought down to the anus; its lower end is temporarily closed using a few large sutures.

(3) The cellular retro-rectal space is now opened by cutting through the meso-rectum and dissection is carried downwards in the midline using the finger, the hand or a swab on a holder until the level of the pelvic diaphragm is reached.

Perineal Approach. (4) The anus is dilated and an incision is made along its posterior circumference at the line of the ano-cutaneous junction. The wall of the anal canal is then dissected off the external sphincter and after a few muscle fibres have been split longitudinally at the upper border of the external sphincter one meets the retro-rectal dissection of the abdominal approach.

(5) With the aid of a curved clamp introduced through this opening, the resected lower end of the colon is grasped and pulled down to the level of the skin incision. The lower end of the colon is reopened and its posterior margin is sutured to the posterior cutaneous lip of the retro-anal incision.

(6) Two Kocher's forceps are inserted, one blade into the lower colon, the other into the rectum; their points meet in a V high up in the bowel and their bases are held apart so that they come to lie at the lateral angle of the colon and anus. The forceps are tightened and then tied together. The colon cannot now retract and the forceps produce haemostasis. After a few days a longitudinal enterostomy opening between the colon and the rectum is produced. The newly fashioned rectum has an anterior part which is aganglionic, reflex control of defaecation thus being assured, and a posterior part composed of colon which will ensure mobility.

I have operated on 11 cases of Hirschsprung's disease using this technique; this is obviously too small a series for statistical purposes but I know that some French, Spanish, Finnish and Swiss surgeons have adopted this operation with results similar to mine. In every case we have been struck by a complete absence of operative shock and by the fact that spontaneous stools are passed within two to four days. Cutting out of the enterostomy forceps takes about a week followed by scarring without complications. The functional result has always been perfect and radiological studies have shown complete regression of colonic dilatation and a normal diameter after an interval of about two to four months.

All these cases show an improvement as good as those operated on by Swenson's method, but I realize that this alone will not convince experienced surgeons who are anyway getting regularly satisfactory results. There are however two particular aspects of the operation which I think constitute a distinct improvement on the old technique. Firstly, this operation is the only one which allows re-operation on cases of 'failed' Swenson's operation, both in failures due to insufficient resection of the lower segment and in those with stenosis of the anastomosis. This advantage has already been recognized by numerous surgeons. Secondly, the most important advantage of the operation is that it allows a considerable lowering of the age limit at operation. Most authors agree that Swenson's operation is dangerous in the newly born because of the difficulties encountered in dissecting the rectum at that age. Swenson himself advises against recto-sigmoidectomy until the child is at least 12 to 18 months old, and suggests that, if necessary, a temporary colostomy only should be carried out.

When recto-sigmoidectomy is performed during the first months of life, the results are often unsatisfactory because in order to save a sufficient amount of gut for proper function of the anal reflexes one is forced to preserve too much of the internal sphincter and it is often necessary to perform a complementary sphincterotomy. The technique that I have described overcomes these disadvantages. I have operated on eight children of less than 6 months of age, five of whom were less than 3 months old, and I have noticed that the younger the child the better have been the operative results and the quicker the return to normal function. Realizing the particular seriousness of congenital megacolon in the neonatal period, and the dangers of a temporary colostomy at this age, we believe that the introduction of a curative operation for Hirschsprung's disease in infancy will allow us to save more children suffering from the so-called 'malignant' form of the disease in the neo-natal period.

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INTESTINAL OBSTRUCTION IN THE NEWBORN INFANT*

BY

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The syndrome known as mechanical ileus or intestinal obstruction is a many-sided problem, the solution of which, in childhood and especially in the newborn infant, is one of the most difficult tasks of the paediatric surgeon, as regards both diagnosis and treatment.

The diagnostic difficulties are due above all to the fact that just at this age the pathological changes causing intestinal obstruction are so numerous. As intestinal obstruction is no more than a symptom, the physician diagnosing it is at most half way to recognition of the disease. The site and type of obstruction are not as yet clear.

The difficulties in treatment arise from the fact that ileus is not only a local affection but also a grave general disease in which quick decisions must be made.

Clinical Features

The clinical picture depends essentially on three factors: on the level of the obstruction, on its duration and on whether it is complete or partial. In high-seated obstruction vomiting is one of the first signs and abdominal distension is limited to the epigastrium. In low-seated obstruction distension of the whole abdomen precedes vomiting. In the newborn infant swallowed air reaches the rectum only after 12-24 hours. Therefore if the obstruction is at a low level, abdominal distension will rarely be present before 12 hours have elapsed. On the other hand, it should be remembered that meteorism during the first 12-36 hours of life may be physiological. In partial obstruction, such as congenital stenosis of the intestine, vomiting is the first and most striking symptom, while abdominal distension may be minimal because the intestinal air is able to pass through the stenosis.

Investigation of bowel function in the first days of life, that is to say the presence or absence of meconium, may provide important clues in the diagnosis of intestinal obstruction, although no hard and fast rules exist in this respect. Delayed passage of meconium should always lead one to suspect low intestinal obstruction, such as atresia of the rectum or colon, meconium ileus or Hirschsprung's disease, although this symptom may also occur in normal babies. On the other hand, evacuation of meconium does not exclude a primary high-seated intestinal obstruction, since meconium is produced in all parts of the intestinal tract and bile pigments reach the intestine by way of the blood.

Microscopical examination of the meconium for cornified epithelial cells and lanugo hairs makes it possible to distinguish between cases with early primary obstruction of the intestine and those in which the obstruction developed later in foetal life by strangulation, volvulus or intussusception. In primary congenital atresia of the bowel these meconium elements are absent.

Radiology

Radiological findings are of prime importance in diagnosis. In every case of ileus in the newborn infant radiological examination in the upright position is called for. Plain films are important since conclusions may be reached as to the site of the obstruction from the number and position of distended loops and fluid levels. In duodenal obstruction the radiological picture is typical. It shows a dilatation of the stomach and only one pathological fluid level on the right of the spine (Fig. 1). The corresponding finding at operation in such a case is seen in Fig. 2. The superior segment of the duodenum is greatly distended and as large as the stomach. In lower intestinal obstruction a plain film in the upright position reveals multiple distended loops and fluid levels (Fig. 3).

Furthermore, an enema with a contrast medium should in no case be omitted, as in newborn babies it is often impossible to decide whether the distended loops belong to the small bowel or to the colon. Such a procedure also provides valuable information as to the permeability and calibre of the colon and the site of the proximal colon. It may thus reveal

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

FIG. 1.—Duodenal atresia in a 5-day-old infant.

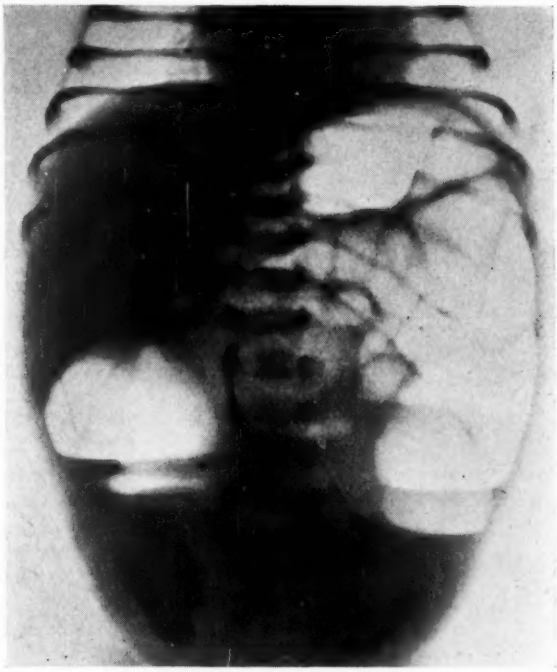

FIG. 3.—Multiple distended loops and fluid levels in lower intestinal obstruction.

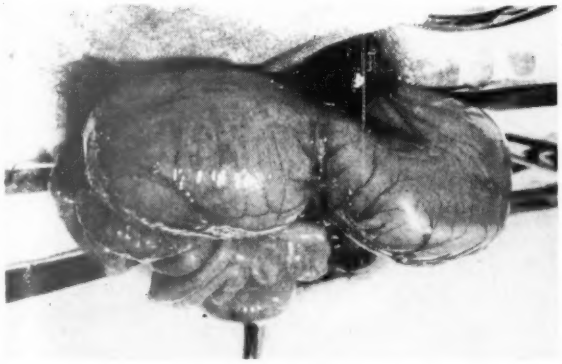

FIG. 2.—Operative findings in duodenal atresia. Greatly dilated superior segment of duodenum.

the presence of atresia, Hirschsprung's disease or ma rotation.

I arium is generally used for contrast enema, but the use of resorbable preparations, such as Ioduron or riopac, is advisable at least in cases of suspected per orations.

(ral administration of barium should be avoided as t may change the patient's condition for the wo e and thereby complicate operation. It is, mo eover, dangerous if aspiration occurs. A further disadvantage of oral administration as compared with an enema is loss of time. Long radiological procedures may mean that the right moment for operation is missed. It is valueless to endanger the child's life by long drawn out diagnostic procedures, since laparotomy is indicated in any case, at which diagnosis can be completed.

Preliminary Treatment

Apart from local symptoms, intestinal obstruction results in disturbances of the general condition.

Loss of fluid due to vomiting and reduced resorption from the bowel produce dehydration and disturbances in electrolyte balance, such as hypochloraemic alkalosis and hypokalaemia. Intraintestinal and intraperitoneal transudation produce hypoproteinaemia by loss of plasma. Respiratory difficulties owing to abdominal distension may result in anoxaemia and cyanosis.

Treatment must first of all aim at combating these general disturbances. It would be a grave mistake to expose the baby to the danger of operative shock without adequate preliminary treatment. This consists of the supply of fluid, electrolytes, blood and plasma by intravenous infusion, and employment of a gastro-intestinal suction system. The decrease of abdominal distension by means of a

naso-gastric tube facilitates operative intervention and diminishes operative shock. Intestinal suction is not only of great use in pre-operative treatment, but also during post-operative care, since it prevents paralytic ileus.

Types of Intestinal Obstruction

The most frequent disorders that the surgeon has to keep in mind are summarized in Table 1. It is clear from this Table that as a rule we have to deal with congenital malformations.

TABLE 1

CAUSES OF INTESTINAL OBSTRUCTION IN THE NEWBORN INFANT

Atresia and stenosis: duodenum, jejunum, ileum, colon, rectum, anus
Annular pancreas
Meconium ileus
Disturbances of foetal intestinal rotation: nonrotation, malrotation, common mesentery
Peritoneal bands
Meckel's diverticulum, omphalo-mesenteric duct
Enterogenous cysts (duplication)
Mesenteric cysts
Intestinal polyps
Intussusception
Megacolon (Hirschsprung's disease)
Strangulated inguinal hernia
Strangulated diaphragmatic hernia
Peritonitis

Firstly, the malformation may constitute the immediate cause of the obstruction, as in congenital atresia, annular pancreas, peritoneal bands, etc., or secondly, it may only be a predisposing factor, for instance, in cases of common mesentery, persistent omphalo-mesenteric duct or in diaphragmatic hernia. Thirdly, we have congenital defects, predominantly functional in type, such as meconium ileus and Hirschsprung's disease.

Atresia and Stenosis. In congenital atresia and stenosis of the small intestine, or more rarely of the colon, we have to distinguish between primary and secondary forms.

Primary atresia and stenosis is due to a persistence of epithelial proliferation existing during the fifth to twelfth weeks of foetal life and occluding temporarily the lumen of the intestinal tract. Remaining portions of these epithelial masses may persist as one or several mucosal septa with or without a central opening which obstruct the lumen. Primary atresia and stenosis manifest themselves only by a difference in calibre. No interruption in intestinal continuity can be noticed from the outside (Figs. 4-7).

On the other hand, congenital atresia may also be due to a pathological process during the foetal period which causes secondary obstruction of the bowel. Pathological processes, such as foetal volvulus, intussusception, incarcerated hernia and meconium ileus, may cause local necrosis of an intestinal segment, thereby producing atresia. These secondary atresias, which are commonly situated at the level of the ileum, are characterized by a gap between the bowel ends or a cord which usually has no mucosal lining. Cicatrization at the ends of the atretic segments and defects in the mesentery are frequent findings. Fibrous nodules on the serous coat and areas containing calcified debris are the remnants of former perforation.

We have observed a case of intestinal atresia in which the collapsed distal stump still contained the remains of an invaginated segment. In another case an incarceration of the lower ileum in an omphalocoele produced a secondary atresia (Figs. 8 and 9).

While in former times operative treatment of atresia or stenosis was rarely successful, modern operative technique and especially adequate post-operative care have considerably improved the prognosis. As a rule the surgeon will try to overcome the obstruction by entero-anastomosis, the method of choice being end-to-end anastomosis as an initial procedure. Enterostomy as a palliative procedure should be considered only in cases in which the obstruction is situated in the terminal ileum or more distal to it. Enterostomy at a higher level is always fatal because of the excessive loss of fluid.

In the performance of entero-anastomosis the difference in size of the pre- and post-stenotic segment may cause some difficulty. In this situation the decompression of the proximal dilated intestine by puncture, suction of direct opening and the injection of normal salt solution into the collapsed narrow distal segment may overcome the discrepancy in size.

In cases of duodeno-jejunostomy for duodenal stenosis or atresia, the passage of a transanastomotic feeding tube with its top lying in the contracted jejunum is advisable because it allows early feeding and dilatation of the distal contracted loops.

But even in correctly performed anastomosis dilatation of the proximal segment with failure of propulsive activity may persist. Resection of the dilated proximal bulb before end-to-end anastomosis seems therefore to be indicated, especially in cases of secondary atresia with cicatrization of the stumps.

Meconium Ileus. A special kind of intestinal obstruction in the newborn infant occurs in meconium ileus, which requires medical as well as

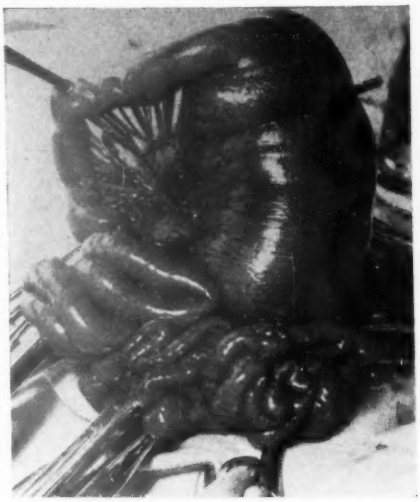

FIG. 4.—Primary stenosis of jejunum.

FIG. 5.—Primary double stenosis of jejunum.

FIG. 6.—Removed and opened specimen (case shown in Fig. 5) with two mucosal folds which formed the stenosis.

FIG. 7.—Small opening in septum causing stenosis (case shown in Fig. 5).

surgical treatment. Meconium ileus is a typical example of intraluminal obstruction, which is caused by an abnormal inspissation of the meconium, especially in the lower segments of the ileum. The abnormal consistency of the meconium is due not only to a deficiency of pancreatic enzymes as a consequence of the co-existing fibrocystic disease of the pancreas; it is rather the expression of a generalized disease of the secreting glands, which is known as mucoviscidosis. The mucous glands of the bowel, too, produce an exceedingly sticky secretion which is firmly attached to the inspissated meconium.

Operation reveals dilated jejunal loops filled with gas and thick meconium, the ileum appearing like a string of beads due to greyish, putty-like knots. The colon is generally empty (Fig. 10).

The diagnosis is already evident from the radiograph (Fig. 11). The dilated upper loops of the intestine do not present fluid levels in the picture in

FIG 8

FIG. 10.

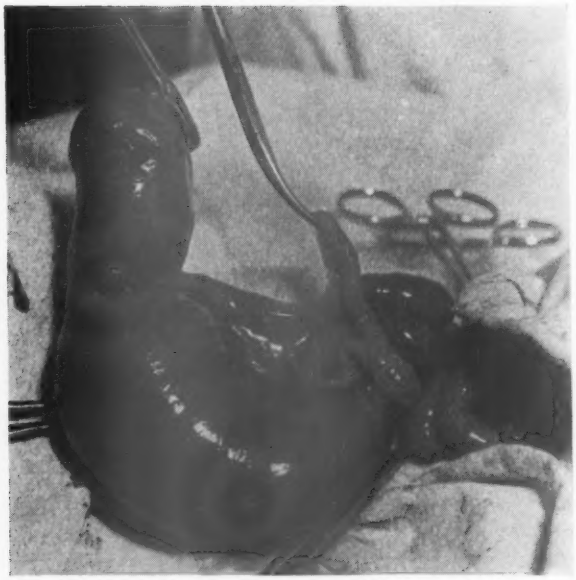

FIG. 9.

FIG. 11.

FIG. 8.—Omphalocoele in a newborn baby with a very narrow umbilical ring and incarcerated transparent mass.

FIG. 9.—Finding at operation in case shown in Fig. 8: secondary atresia of lower ileum owing to strangulation by narrow umbilical ring during foetal period.

FIG. 10.—Typical appearance of meconium ileus.

FIG. 11.—Meconium ileus with several dilated loops of different size without fluid levels. Mottled meconium masses on right side.

FIG.

FIG. 12.—Meconium ileus with volvulus.

the upright position because the thick gluey meconium adheres to the intestinal wall. The meconium masses manifest themselves by granular spots. The mottled appearance is due to infiltration of the meconium by small air bubbles.

An enema with a contrast medium shows the colon, which is free of meconium and has the appearance of a so-called 'microcolon'.

Meconium ileus may produce several complications even during the foetal period. The accumulated meconium masses may cause ischaemia, necrosis and perforation of the intestinal wall, thus producing aseptic meconium peritonitis, which may cause adhesions and strangulations. These cases present typical calcified granulations in the peritoneal cavity corresponding to foreign body reactions.

Not infrequently the enlarged and heavy loops of the upper intestine become twisted upon themselves and give rise to volvulus formation with or without secondary atresia of the strangulated segments. Fig. 12 represents a volvulus of this origin. Reduction of the volvulus reveals a completely squashed loop (Fig. 13). In this way secondary atresias are formed. In the case of Fig. 14 the same process took place at an early stage of foetal life. The result is a complete interruption of the continuity of the bowel.

In the treatment of meconium ileus the following facts are of crucial importance. We know that it is impossible to estimate the degree of severity by clinical and radiological investigations, or to distinguish uncomplicated from complicated cases with volvulus, perforations and secondary atresias. Laparotomy is therefore indicated in any case.

FIG. —(Case shown in Fig. 12.) Reduction of volvulus reveals a completely squashed loop (secondary atresia).

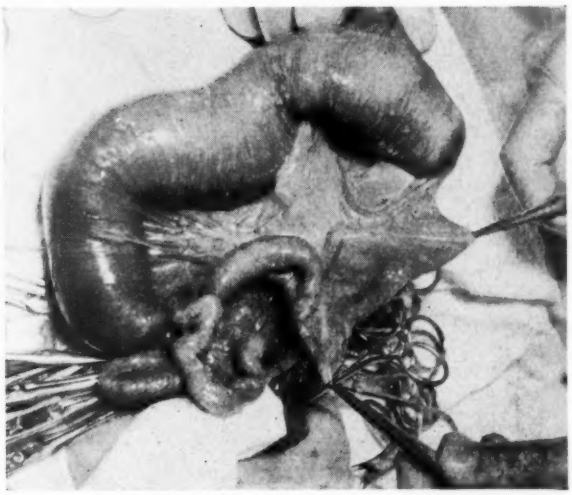

FIG. 14.—Meconium ileus with secondary atresia of lower ileum caused by volvulus at an early foetal stage.

In uncomplicated cases the first thing is to relieve the increasing and dangerous intestinal distension by suction. The removal of the obstacle, the sticky thick meconium masses in the ileum, cannot possibly be performed by mechanical procedures. On the other hand, it has been proved that after administration of pancreatic enzymes the meconium may be expelled spontaneously in a few days. Therefore we make a small incision in the lowest portion of the distended intestine, deflate the upper loops and introduce a powdered preparation of pancreatic enzymes into the intestinal lumen. Before we close the abdominal wound a tube is passed through the nose into the stomach and duodenum under direct vision. In this way the intestine can be deflated during subsequent days and further proteolytic enzymes can be instilled through the tube.

While this simple treatment is successful in uncomplicated cases, more severe forms require enterostomy, through which enzyme instillations can be administered. Although results as regards relief of the obstruction seem at first glance to be satisfactory, long-term results are disappointing. Most of these babies die sooner or later of overwhelming pulmonary infection in spite of adequate diet, administration of pancreatic enzymes and antibiotic treatment.

Abnormal Bowel Positions. Other not infrequent conditions causing intestinal obstruction in the newborn infant are abnormal positions of the bowel due to lack of normal rotation of the midgut during the foetal period. The recognition of such conditions often demands considerable spatial imagination on the part of the surgeon.

FIG. 15.—Volvulus in a newborn infant with common mesentery.

FIG. 16.—Infarction of intestine in a newborn infant owing to common mesentery with volvulus.

The normal position of the bowel is reached by a rotation of the midgut of 270° in an anti-clockwise direction. The midgut represents that portion of the alimentary tract from the duodenum to the middle of the transverse colon, which is supplied by the superior mesenteric artery. To reach a normal position, the mesentery of the ascending colon has to become fixed to the right posterior abdominal wall.

The rotation may be incomplete, it may stop after 90° or 180° or take place in a reverse direction. In addition, failure of attachment of the mesentery along the right lateral and posterior abdominal wall is nearly always present, but this anomaly, so-called common mesentery, may also be encountered in cases with normal rotation.

The common mesentery can obviously give rise to twisting of the entire mass of the small intestine and colon around the small mesenteric root, which generally takes place in a clockwise direction (Fig. 15). The twisted mesenteric pedicle may strangulate the inferior part of the duodenum and produce symptoms of duodenal stenosis. In rare cases, in which the twisted mesenteric root strangulates the mesenteric vessels, infarction of the entire intestinal mass may ensue (Fig. 16).

Another anomaly causing obstruction of the duodenum results from compression of the lower duodenum by an overlying caecum or ascending colon. This condition may be encountered in cases with incomplete or reversed rotation, in which the caecum is placed in the duodenal area and becomes fused with the posterior abdominal wall.

A third form of obstruction may be seen in cases with reversed rotation when the duodenum reaches its final position in front of, and the transverse colon behind, the mesenteric root. This condition, known as retroposition of the transverse colon, may produce an obstruction of the proximal colon, especially if it is complicated by an additional volvulus. Visualization of the colon by radiography with contrasting barium almost always supplies significant information. When the caecum and ascending colon are displaced to the left and upper part of the abdomen a volvulus of the midgut should always be suspected (Figs. 17 and 18).

Even so-called internal hernia, or mesocolic hernia, may be due partly to anomalous intestinal rotation. The tendency of the proximal colon to reach its normal position on the right, independently of previous foetal rotation, may in cases of non-rotation or reversed rotation lead to partial or total envelopment of the small intestine by the ascending mesocolon. Thus internal hernia is produced in which intestinal loops may be incarcerated (Fig. 19).

Operative treatment of the abnormal position and rotation should not only comprise the reduction of a volvulus or the severance of strangulating bands, but the ascending colon should be fixed to the right posterior abdominal wall in a normal position. Our own experience with mesenteric vessels has taught us that fixation at the right site is absolutely essential in order to obtain optimal blood supply.

Enterogenous Cyst. Another congenital malformation which has to be taken into account in cases of intestinal obstruction is the enterogenous cyst, or duplication of the bowel, which is seen in about 20% of cases even in the neonatal period.

These structures, which may be tubular, cystic or diverticular, can branch out from the entire bowel, but they usually lie in the region of the lower ileum and caecum. In spite of this, they have embryologically nothing to do with Meckel's diverticulum. The duplications are due to disturbances during an early foetal period in which

FIG. 17.—Retroposition of transverse colon (reversed rotation) with additional volvulus. Caecum lies in an anomalous position in left upper side of abdomen. Filling defect of transverse colon due to compression by twisted mesenteric pedicle.

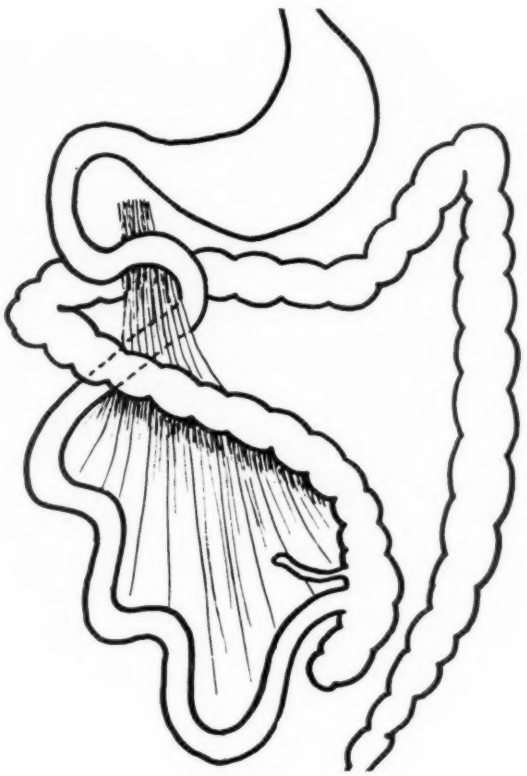

FIG. 18.—Diagram of case shown in Fig. 17.

FIG. 19.

FIG. 19.—Internal hernia containing several incarcerated loops. Hernial sac is formed by mesentery of ascending colon.

FIG. 20.—Intussusception in a newborn baby with intussusceptum protruding from anus owing to ileal duplication.

FIG. 21.—Resected ileo-caecal specimen from case shown in Fig. 20. Note enterogenous cyst in lower ileum.

FIG. 22.—Multilocular lymphatic mesenteric cyst producing intestinal obstruction and stasis of adjacent bowel segment.

FIG. 23.—Hour-glass-shaped chylous mesenteric cyst which contained large quantity of yellow, milky fluid.

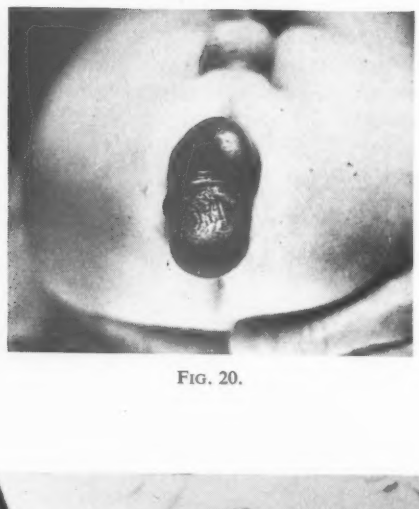

FIG. 20.

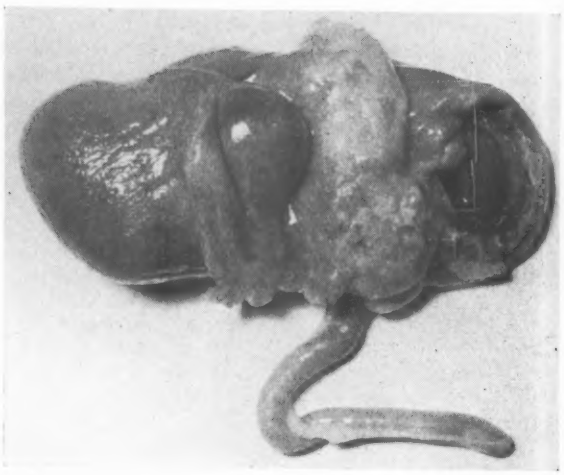

FIG. 21.

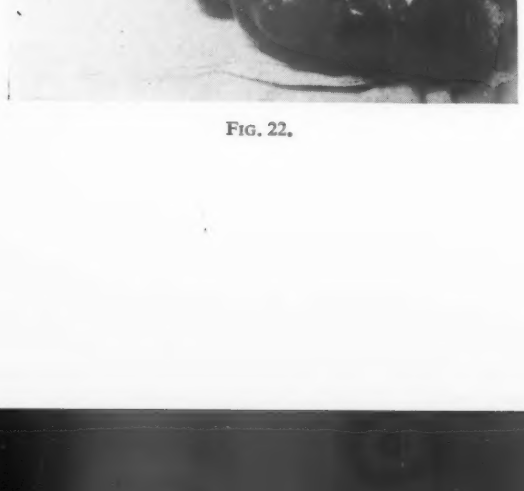

FIG. 22.

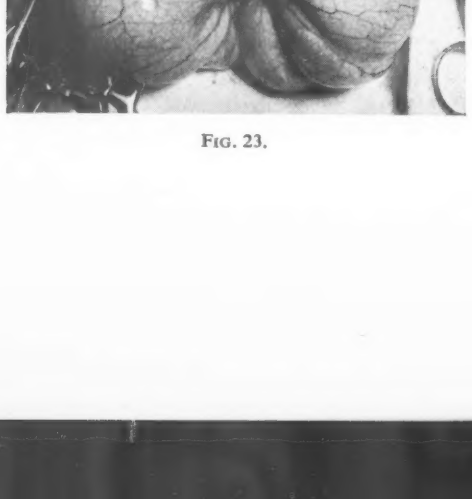

FIG. 23.

the chorda dorsalis is separated from the entoderm.

These cystic structures, closely attached to some portion of the alimentary tube, grow continuously in size by retention of secreted mucosal fluid, thereby causing obstruction of the intestinal lumen.

Since these duplications are supplied with blood by the same vessels as is the adjacent bowel, it is impossible to resect the cyst without impairment of the blood supply to the contiguous intestinal segment. Therefore the segment in question has also to be resected.

Cysts of this type may not only produce intestinal obstruction, but they may also act as a leading point in the development of intussusception. Fig. 20 shows a newborn baby with intussusception, the tip of the intussusceptum protruding from the anus. It contained a single cystic tumour. Surgical reduction of the intussusception presented no difficulty. After reduction, the cystic tumour proved to be a duplication of the lower ileum which had passed the whole colon within a few hours. Ileo-caecal resection was performed (Fig. 21) and the post-operative course was uneventful.

Mesenteric Cyst. Other structures, which have to be differentiated from enterogenous cysts, are lymphatic mesenteric cysts. These tumours rarely cause intestinal obstruction in the newborn infant. The cysts are thin-walled and multilocular and often have the shape of an hour-glass. They contain serous, colourless or chylous yellowish fluid (Figs. 22 and 23). Smaller cysts can be dissected out from the mesentery, while large ones require intestinal resection and end-to-end anastomosis.

Hirschsprung's Disease. Lastly I should like to make brief mention of Hirschsprung's disease or aganglionic megacolon.

Newborn babies with this disease almost always show difficulty in evacuation of meconium, constipation, vomiting and abdominal distension, all symptoms of intestinal obstruction which, however, vary in intensity.

Often an obstruction of the small bowel is suspected, particularly as plain radiography shows dilated loops with fluid levels. To exclude this a contrast enema is absolutely essential. It shows that the dilatation is situated in the colon. The picture typical for Hirschsprung's disease with contracted rectosigmoid is, however, frequently not so marked in the newborn baby as it is some weeks later. In case of doubt a biopsy from the rectal musculature should be performed. Microscopical examination will prove whether ganglion cells are present or not.

One rare though severe complication of Hirschsprung's disease, which may occur in the first days of life, is perforation of the distended colon (Fig. 24). We have observed it in three cases: twice in the region of the left colonic flexure and once in the caecum. In all three cases colostomy was performed at the site of perforation with good results.

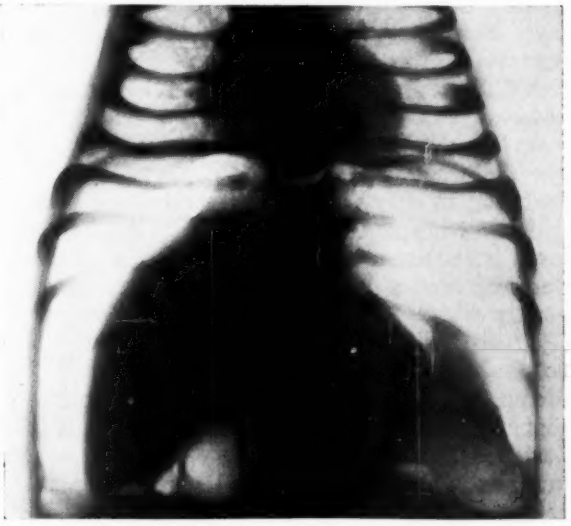

FIG. 24.—Pneumoperitoneum after perforation of colon in a 2-day-old baby suffering from Hirschsprung's disease.

In the treatment of megacolon in the newborn baby conservative measures will, as a rule, be resorted to at the start with frequent enemas to combat the gaseous distension. In most cases this will prove successful for some time. Should difficulties arise in controlling the distension, temporary colostomy is advisable. Nevertheless, we do not hesitate in such cases to perform rectosigmoidectomy by Duhamel's method even in the first few months of life. This retrorectal pull-through is technically simple, as the rectum has to be mobilized only on its dorsal side, which is easy to accomplish. The intervention is therefore relatively short and produces no shock. It prevents secondary strictures at the site of the anastomosis and disturbances of bladder function.

We have employed this method in 15 cases, six of whom were infants aged from 6 weeks to 8 months. Results were very satisfactory regarding healing of the megacolon, but later investigation of these children showed that they suffered from numerous evacuations, some even from actual diarrhoea, as a result of the destruction of the internal sphincter.

We therefore advise the following modification of Duhamel's procedure: we incise the posterior wall of the rectum 1·5 cm. above the internal sphincter, thus conserving this important muscle. The proximal stump of the colon is pulled through this incision and not through one at the level of the anus. Details of this special technique will be published shortly. The apparent level of the transitional zone in young infants may be misleading; biopsy of the colon muscle tissue during operation is therefore advisable.

A difficult problem in the newborn period, which, however, arises only seldom, is presented by those cases in which the aganglionic zone extends throughout the whole colon as far as the lower ileum. Deflation by an enema is in these cases ineffective and the clinical picture corresponds to that of a lower stenosis of the small bowel. We recently observed such a case, which at operation showed a greatly dilated and hypertrophic lower ileum (Fig. 25). Ileostomy was performed and total colectomy was provided for at a later date. Unfortunately the infant died of peritonitis. Microscopical examination revealed that the hypertrophic ileal loops contained ganglion cells in normal numbers whereas the terminal part of the ileum contained only a few ganglion cells, and throughout the caecum and colon they were completely absent. The peculiar thing about this case was that the child showed no symptoms of intestinal obstruction as long as she was breast-fed. Only after changing to artificial feeding did such symptoms appear.

FIG. 25.—Hirschsprung's disease with aganglionic zone throughout colon and terminal ileum: 1 = hypertrophic and dilated ileum with normal number of ganglion cells; 2 = only few ganglion cells; 3 = ganglion cells completely absent.

In conclusion I should like to emphasize that I am fully aware of the incompleteness of my remarks concerning intestinal obstruction in the newborn baby. Many problems could only be touched upon.

Intestinal obstruction in a newborn baby is always a delicate and critical matter demanding rapid decisions. Success in these cases depends not only on early diagnosis and appropriate operation, but also upon the quality of pre- and post-operative care, of suitable anaesthesia, and, last but not least, upon the constant and untiring efforts of our nurses.

SIMULTANEOUS INTRA- AND EXTRAPULMONARY SEQUESTRATION*

BY

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Pulmonary sequestration has attracted considerable attention in recent years. Many papers reporting typical cases have appeared in the literature. Repetition of material already extensively reported will not be attempted (Bariéty and Coury, 1947; Pryce, Sellors and Blair, 1947; Bruwer, Clagett and McDonald, 1950, 1954; Kergin, 1952; Santy, Bérard, Gaby and Huu (1952); Boyd, 1953; Hertzog, Toty, Personne and Gilbert, 1953; Razemon, Houcke and Razemon, 1953; Monod, 1954; Boyden, 1955, 1958; Bruwer, 1955; Pryce, 1946; Smith, 1956; Procházka and Steinhart, 1957).

The case described here is a very rare form of pulmonary sequestration, which justifies its publication.

Case Report

The patient was a 15-month-old boy (No. 1323/58) who at the age of 3 weeks developed pneumonia, seen in the radiograph as a pericardial infiltration above the diaphragm (Fig. 1). Despite the usual antibiotic therapy, it subsided surprisingly slowly (Fig. 2). A follow-up radiograph at 11 months of age showed a sharply defined elliptical shadow, the size of an egg, lying paravertebrally below the diaphragm and superimposed on the gastric bubble (Figs. 3 and 4). Following radiological examination, including upper gastro-intestinal barium studies, retroperitoneal air insufflation, bronchography and pyelography, the provisional diagnosis of retroperitoneal tumour, probably of neurogenic origin, was made. Surgery was advised after further regression of the pneumonitis.

The operation (Kafka, Brodský, Kudrnová, anaesth. Dra[illegible]ka) was performed on October 18, 1958. An oblique incision was made in the left epigastrium. The tumour was found to be on the posterior surface of the stomach (Fig. 5) on the fundus and on the cardia. It was a thin-walled cyst fixed flat against the stomach and was separated by sharp dissection. Its superior end continued as a narrower cylindrical cyst, lying on the oesophagus, right up through the hiatus. The lumen of this narrow cyst was separated from its gastric portion only by an internal membrane.

The oesophagus was pulled downwards and the cyst further dissected. On opening the cyst wall and inserting a probe, it was found that the cyst continued into the thorax in a dorso-latero-cranial direction. By prolonging the incision through the seventh intercostal space an additional thoracophrenotomy was performed. The cyst, or rather its stem, 10×12 mm. in diameter, diverged from the oesophagus to enter the dorso-basal segment of the left lower lobe. A large coiled artery ran into it, traversing the diaphragm and arising from the abdominal aorta. This was ligated and a resection of the dorsobasal segment, together with the entire cystic structure, was carried out (Fig. 6).

Specimen (Fig. 7). The resected specimen consisted of two parts. The superior portion was in the shape of a triangle, at the apex of which were bronchi, artery and vein running into the resected segment of the left lower lobe. On probing, the bronchus did not communicate with the cyst, which formed the posterior wall of the resected segment. The upper portion of the cyst was thick-walled, containing almost cartilaginous elements; its distal part narrowed into a thick stalk 6-7 cm. long, without interruption of the cyst lumen. An ovoid, thin-walled segment the size of an egg was situated on the inferior end.

Histology. (Žaková, Second Institute of Pathological Anatomy, Charles' University, Prague; Case No. 3164/58.) The wall was formed by two layers of smooth muscle fibres. Exterior to this was a layer of connective tissue showing elastic degeneration, and scattered seromucous gland. Ciliated cylindrical epithelium on a basal membrane formed the cyst lining (Figs. 8 and 9).

The post-operative course was uneventful; one year after operation the patient's condition now appears excellent.

Discussion

In the present communication we wish to outline certain characteristics of this syndrome: the simultaneous occurrence of intra- and extralobar sequestration, the subdiaphragmatic position of a part of the dumb-bell-shaped cyst, the blood supply and, finally, problems of diagnosis before and during operation.

* paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

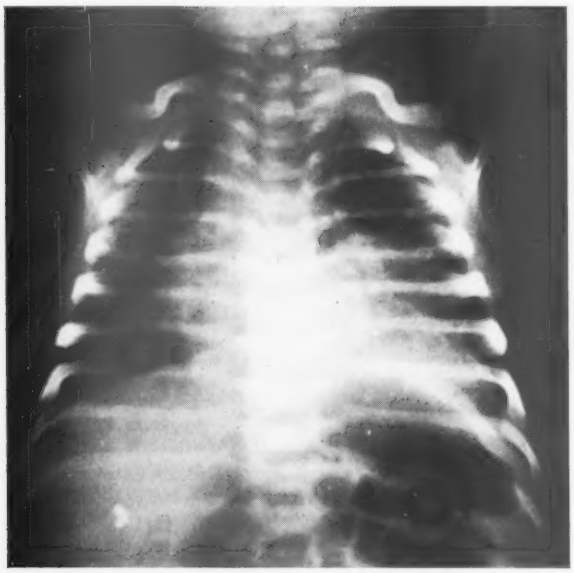

FIG. 1.—Admission radiograph showing consolidation of left lower pulmonary field.

FIG. 2.—Radiograph taken two months after that of Fig. 1, showing slow improvement of pulmonary condition following chemotherapy.

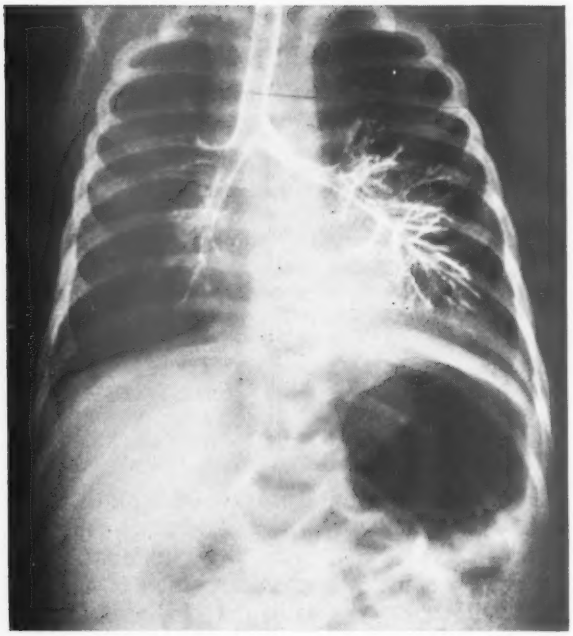

FIG. 3.—Bronchogram showing shadow below diaphragm superimposed on gastric bubble.

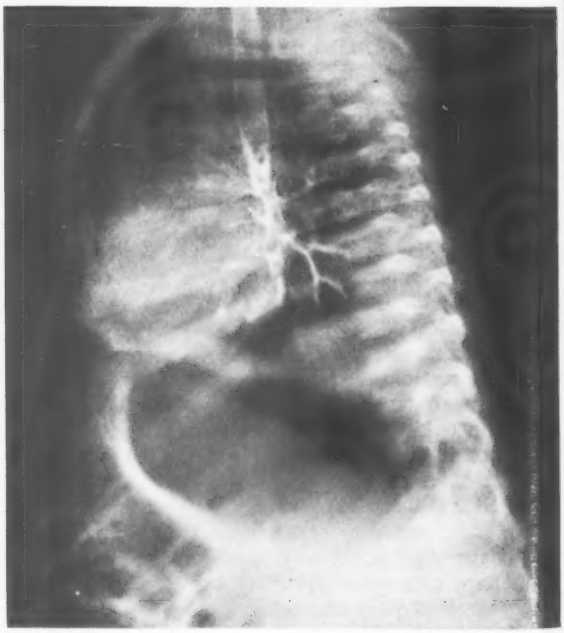

FIG. 4.—Bronchogram: lateral view showing shadow below diaphragm just in front of vertebral column.

FIG. 5.—At operation the tumour was found lying at posterior surface of stomach.

FIG. 7.—Excised specimen.

FIG. 9.—Section of cyst wall (high magnification).

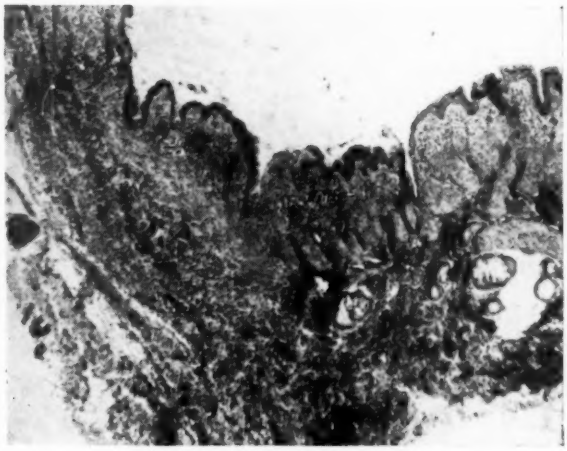

FIG. 8.—Section of cyst wall.

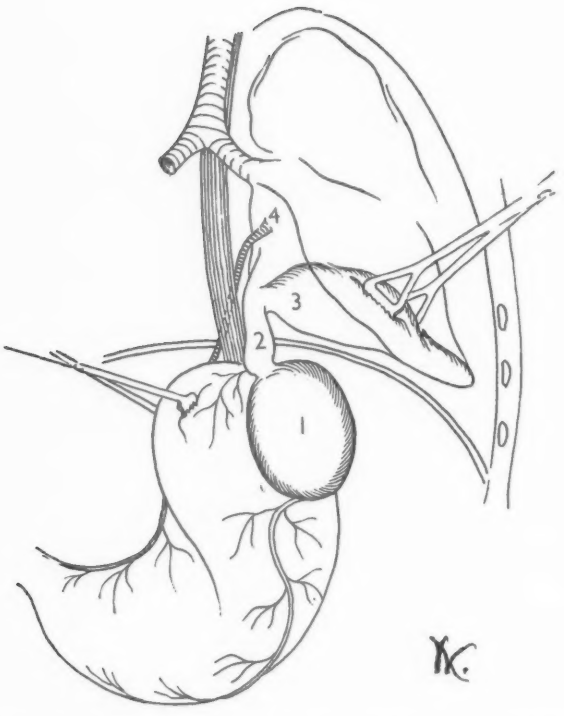

FIG. 6.—Schematic drawing showing findings at operation: 1. Spherical cyst; 2. Tubular prolongation; 3. Left lower pulmonary lobe; 4. Bronchial artery.

Neither aetiology nor classification of this disease entity have been agreed upon (Gebauer and Mason, 1959), and the term sequestration itself does not seem to cover the case. Since this term has been widely applied as a result of publications by Pryce *et al.* (1947) and others, we shall continue to use their terminology. The term "foregut cyst" (Hössli, 1950; Roemer and Mollowitz, 1957) or 'dysembryopathy' (Bert and Fischer, 1910; Petřiková, Polák and Stolz, 1952; Breton and Dubois, 1957) seems more accurate.

It is known that pulmonary sequestration is one of a group of developmental defects occurring at the site of differentiation of the gastro-intestinal and respiratory tracts from the foregut. It naturally follows that various structures in the lower thoracic area may be involved (Cole, Alley and Jones, 1951), particularly the lower lobe arteries (Cole *et al.*, 1951; Findlay and Maier, 1951; Fry, Arnold and Miller, 1953), mediastinum (Maier, 1948), pericardium (Ladd, 1936; Rusby and Sellors, 1945; Warner, Britt and Riley, 1958) and diaphragm (Cockayne and Gladstone, 1917; Raymond *et al.*, 1956).

The majority of cases present a relatively simple lobar form of pulmonary sequestration (Boyd, 1953; Bruwer *et al.*, 1954; Bruwer, 1955), often supplied by an atypical systemic artery, also referred to as a bronchogenic cyst (Fry *et al.*, 1953; Gross, 1953), Flimmerepithelcysts (Zadek and Riegel, 1958), congenital lung cyst (Kergin, 1952), etc.

Extralobar sequestration has a more complex character. We find it termed 'lower accessory lung' (DeBakey, Arey and Brunazzi, 1950), pulmonary aberrations, supranumerary lung (Gans and Potts, 1950; Raymond, Hardy and Robbins, 1956; Boyden, 1958) located in the pleural cavity (Rusby and Sellors, 1945) as well as in the mediastinum (Maier, 1948) or elsewhere. Some authors do not make a genetic differentiation and maintain that these are quantitative variations of the same developmental defect (Bert and Fischer, 1910; Borovanský and Hněvkovský, 1929; Breton and Dubois, 1957).

The site of the lesion and its embryonic stage determine the degree of tissue differentiation and the location and nature of the malformation. Maier (1948) maintains, for example, that there is no formal differentiation between bronchogenic and enterogenic cysts.

Since the aetiology and exact origin of such developmental errors are still not clear, we do not feel qualified to comment upon them.

Only rarely do both extra- and intralobar sequestration occur simultaneously. And even more rarely is this combined with ectopic location of the extralobar part in the abdominal cavity or below the diaphragm. Cases of isolated ectopy are mentioned by Valle and White (1947) and Raymond *et al.* (1956). Very complex malformations may occur. Such a condition was found in our patient, where a cyst of the stomach and oesophagus was connected with a pulmonary cyst supplied by an anomalous artery arising from the abdominal aorta.

Mention must be made here of what Gross (1953) calls 'duplications of the alimentary tract'. Two cases were presented with simultaneous occurrence of enterogenic cysts in thoracic and abdominal cavities. These should be considered in the differential diagnosis of extrapulmonary sequestration.

From the surgical point of view it is interesting that pulmonary sequestration with arterial anomalies was a problem some 10 years ago, as shown by reports of operative deaths or severe complications in relation (or without relation) to surgery. Fatal haemorrhage was reported by Harris and Lewis (1940), Butler (1947) and Douglass (1948)—see Fry *et al.* (1953). The extensive work of Pryce *et al.* (1947) and others acquainted thoracic surgeons with the problem involved, and today the literature contains more than 110 cases; over 100 have been reported by Bruwer (1955) and 11 cases from the Czecho-Slovakian literature may be added. This

does not include reports of simple bronchogenic cysts (without anomalous artery) with an intrapulmonary or mediastinal localization.

In most uncomplicated cases pre-operative diagnosis is not difficult. Repeated lung infection and a shadow on the radiograph in the region of the dorsobasal pulmonary segment pointing caudally to the midline indicate the lines along which further investigation should be carried out (Wyman and Eyler, quoted by Bruwer (1955)).

There are, of course, circumstances which complicate the diagnosis. These are in the first place inflammatory processes, including lung abscess and tuberculosis, or non-inflammatory processes, such as atelectasis, bronchiectasis, etc. In the second place, difficulties may be encountered in differentiation from pulmonary or extrapulmonary neoplasms (Barthel, 1958). Cases of pulmonary sequestration treated as tuberculosis, even including thoracoplasty, or as pneumothorax from a burst lung abscess have been reported (Table 1).

Even in the course of operation to make the correct diagnosis is not always simple or even possible. Fry *et al.* (1953) admit having performed an operation, supposedly for an enterogenic cyst, without being directed to the right conclusion even by the discovery of an extension through the diaphragm. Only histological examination revealed that it was a case of a pulmonary sequestration.

Similarly, in our case pulmonary sequestration was not suspected, in spite of the finding of a gastric cyst, until probing of the oesophageal cyst revealed its true extent.

TABLE 1
PULMONARY SEQUESTRATION TREATED SURGICALLY IN CHILDREN UNDER 20 YEARS

Author	Cases (no.)	Sex	Age (yr.)	Site	Clinical Diagnosis	Anomalous Artery Derived from:	Operation
Rusby and Sellors (1945)	1	F	19	Left extralobar	Pulmonary cyst or tumour of mediastinum	Pulmonary or bronchial artery	Extirpation
Ravitch and Hardy (1949)	2	M M	12½ 6	L.L.L. R.L.L.	Infected cyst " "	Thoracic aorta (3) Intercostal artery	Lobectomy Lobectomy
Gans and Potts (1950)	1	F	5/12	Left extralobar communication to oesophagus	Oesophageal diverticulum	Pulmonary artery	Extirpation
Hössli (1950)	1	M	5	L.L.L. communication to stomach	Pulmonary abscess		Lobectomy
DeBakey *et al.* (1950)	1	F	7	L.L.L.	Pulmonary cyst (dermoid)	Thoracic aorta	
Cole *et al.* (1951)	1	M	3	L.L.L.	Cyst	Thoracic aorta	Lobectomy
Kergin (1952)	3	M F F	17 19 16	L.L.L. L.L.L. R.L.L. Intra- and extralobar	Cystic disease Infected cyst Intralobar sequestration	Thoracic aorta Subdiaphragm Intercostal artery	Lobectomy Lobectomy Lobectomy
Boyd (1953)	6	M M F F F M	7 5 4 13 9½ 6	R.L.L. R.L.L. L.L.L. L.L.L. L.L.L. L.L.L.	Tuberculosis Pulmonary affection " " " " " " " "	Intercostal artery Subdiaphragm Thoracic aorta " " Subdiaphragm "	
Fry *et al.* (1953)	1	M	19	R.L.L.	Pulmonary cyst (abscess)	Subdiaphragm	Lobectomy
Čermák, Váňa and Rozhold (1955)	2	F F	6 14	R.L.L. R.L.L.	Bronchiectasis ?	Subdiaphragm Thoracic aorta (3)	Lobectomy Lobectomy
Smith (1956)	1	M	18	L.L.L.	Bronchiectasis	Thoracic aorta	Lobectomy
Procházka and Steinhart (1957)	4	M M M F	6 5 6 7	L.L.L. L.L.L. R.L.L. L.L.L.	Tumour or pulmonary cyst Vulvular pneumothorax Sequestration Cyst (Tb empyema)	Thoracic aorta " " Subdiaphragm Thoracic aorta	Segmental resection Lobectomy Lobectomy Thoracoplasty else- Lobectomy [where
Weber *et al.* (1958)	2	F M	3 7½	Intrapulmonary Extrapulmonary (pericardial defect)	Cyst Mediastinal cyst	Subdiaphragm (4) Pulmonary and bronchial artery	Lobectomy Extirpation
Kiraly and Beco	1	M	1¼	L.L.L. and extralobar (subdiaphragm)	Neurogenic tumour	Subdiaphragm	Segmental resection and extirpation (thoracophreno-laparotomy)

Conclusions

The history of our case clearly shows signs typical of pulmonary sequestration, which together with the type of infiltration shown by radiography in the left lower lobe should have directed us towards a correct diagnosis.

The misleading element was the finding of an abdominal tumour in a paravertebral position. This and its shape appeared to indicate a ganglioneuroma.

Tomography and retroperitoneal insufflation were not helpful, since the tumour was in fact partly situated in the retroperitoneal space.

Barium meal showed no pathological changes. On bronchography three branches of the dorsobasal bronchus did not fill right up to their periphery, which was considered incidental to the suspected postpneumonic condition.

For these reasons operation was started with a diagnosis of retroperitoneal tumour, a neurinoma, and no connexion was at first seen between the two conditions, pulmonary and abdominal.

In the course of operation we were surprised to find that (1) the mass was not a ganglioneuroma, (2) it was not wholly retroperitoneal, arching into the abdominal cavity and connecting with the stomach, and (3) it had penetrated through the hiatus along the oesophagus into the thoracic cavity.

Only probing the cyst lumen revealed that the cyst continued high up into the thorax, and the approach was widened into a thoraco-phrenolaparotomy. It then became clear that this was a case of pulmonary sequestration. The anomalous artery could be severed and the entire cystic mass was removed.

Summary

A rare case of dysembryoplasia (foregut cyst) in the region of the respiratory and upper alimentary tracts is described, falling under the heading of pulmonary sequestration as known in the literature.

Thoracophrenolaparotomy in a boy of 15 months revealed connecting masses of cysts, localized in the left inferior lobe (intralobar sequestration with an aberrant artery), passing to the oesophagus (extralobar pulmonary sequestration) and through the hiatus to the stomach (forming the subdiaphragmatic part of the tumour).

The entire cystic complex was removed.

Diagnostic errors and special anatomical conditions in the described case are pointed out. The discussion is supported by a Table covering exclusively surgical cases in children.

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PULMONARY SEQUESTRATION*

BY

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Pulmonary sequestration is a developmental anomaly of the pulmonary and cardiovascular system. It consists of dissociated, non-functioning lung tissue which is supplied by aberrant arteries and has no communication with the normal bronchial system. It may be divided into two types, intralobar and extralobar. This anomaly has become an important and interesting clinical problem in the past 10 years. Most of the cases were diagnosed and treated as lung abscess, empyema or bronchiectasis because the real diagnosis had been overlooked.

The number of reported cases has increased rapidly during the last 10 years. Nevertheless in 1958 Eaker, Hannon and French discovered only 104 cases; Warner, Britt and Riley (1958) reported three cases. In addition I would like to report three cases from the Bremen Children's Hospital.

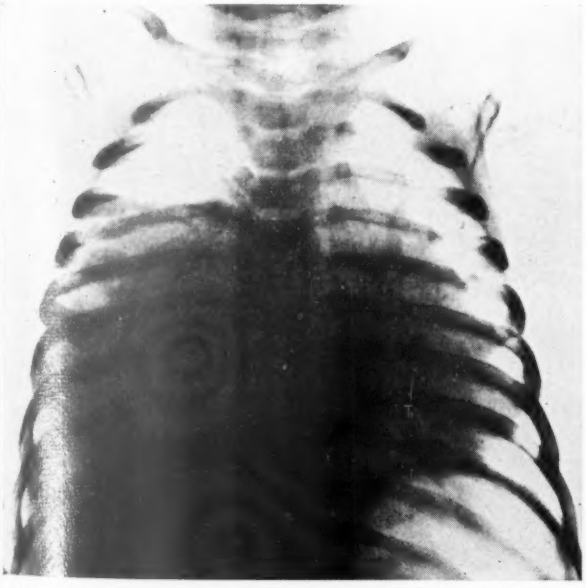

FIG. —Case 1. Large opacity in right hemithorax with displacement of heart and mediastinum to left side.

FIG. 2.—Case 1. On rotation shadow is seen to lie in posterior region of thorax. An area of calcified density is visualized.

Case Reports

Case 1. A 6-month-old girl was admitted because of high fever. A radiograph (Fig. 1) showed an area of opacity in the right lung field. On rotation of the patient it was seen to be in the lower posterior region of the chest wall, and an area of calcified density was visualized (Fig. 2). The heart and mediastinum were shifted to the left side. At operation there was a mass about the size of two fists arising from the right lower lobe, which could not be detached from the lung or diaphragm. Therefore the lower lobe was resected. As we tried to free the adhesion from the diaphragm an accessory artery the size of a pencil was seen arising from the thoracic aorta and running to the lower lobe. Moreover there was an opening about 2·5 cm. in diameter on the right side of the diaphragm containing a mushroom-shaped protrusion of liver, which communicated with the lower lobe through the adhesion tissue.

Unfortunately the child died immediately after the operation. The macroscopical specimen showed a small cystic formation of the whole lower lobe, part of which became a solid yellow area. There was normal lung tissue only at the anterior margin of the lobe. At the

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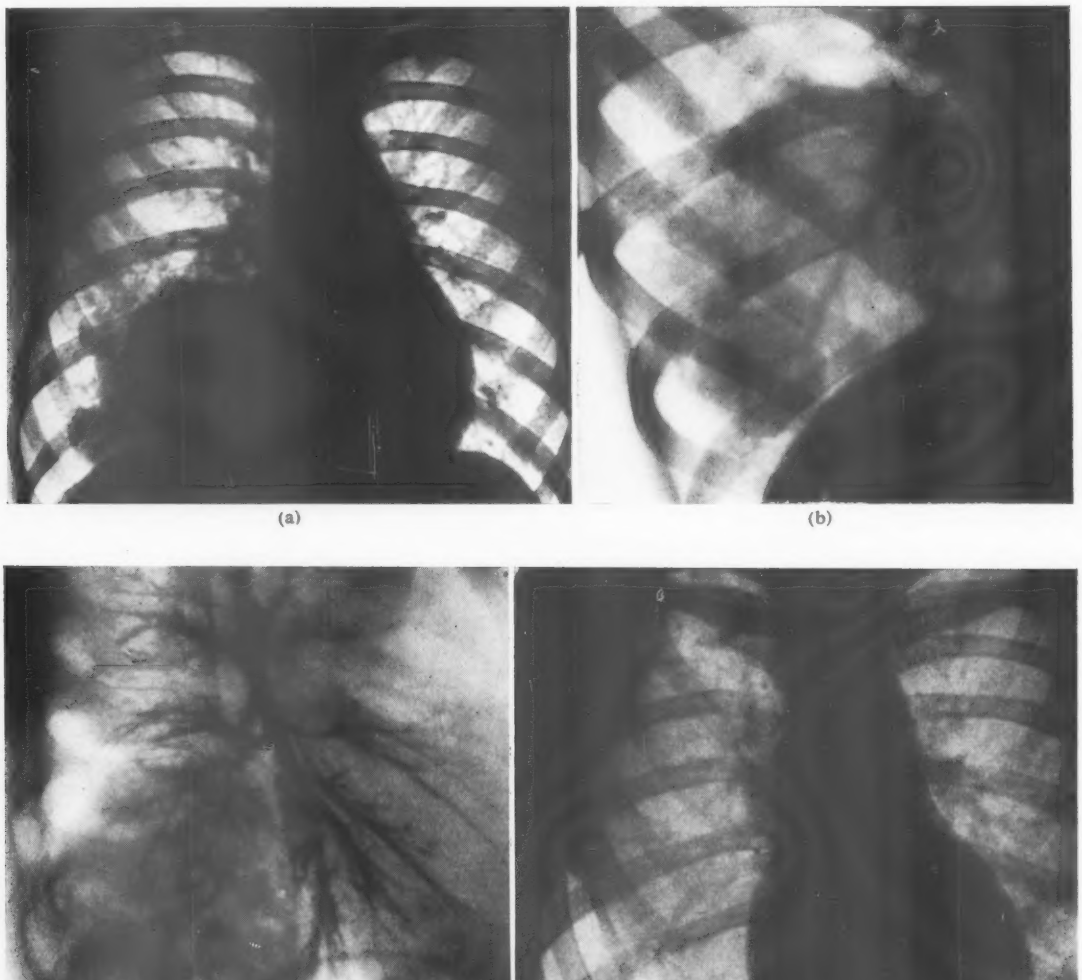
base of the lung there was a communication of the arterial branch into the liver through the opening in the diaphragm. Histological examination showed that the cysts were lined with bronchial epithelium (some ciliated) containing cellular debris and desquamated epithelium.

According to the reported cases in the literature, this case is a rare one. Besides a right intralobar pulmonary sequestration there was a defect of the diaphragm and communication between the sequestration and the liver.

Case 2. A 14-year-old boy without symptoms was admitted because of a tumour shadow in the lower part of the right thorax, which had been found accidentally two years previously on serial radiological examination. There was a dense oval shadow in the posterior part of the right lower lobe (Fig. 3a, b), which revealed a fluid level on the cranial side and had two round protrusions. Bronchographic examination (Fig. 3c) showed that the bronchus segment no. 6 was displaced upward, and no. 9 and no. 10 forward. At operation the lower lobe was seen to be composed of many small cystic tumours. It was impossible to dissect these masses from the lower lobe and therefore lobectomy was performed. The pulmonary ligament contained an abnormal artery about the size of a pencil from the aorta to the lower lobe. There was no post-operative complication and the radiograph showed a satisfactory result (Fig. 3d).

Histological examination showed an area of extensive widening of the bronchi with two large cystic formations in the lower lobe. They were irregularly lined with simple



(a) (b) (c) (d)

FIG. 3.—Case 2. (a and b) Dense oval shadow in lower posterior part of right hemithorax with presence of two round protrusions and a small fluid level; (c) displacement of bronchi of lower lobe ; (d) post-operative radiograph.

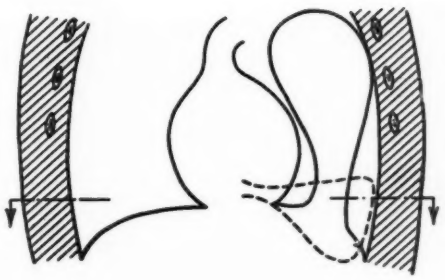
columnar and some stratified columnar epithelium, and contained abundant desquamated epithelium, cellular debris and leucocytes. The surrounding area was composed of respiratory epithelium. At the margin of the lobe there was normal lung tissue with functional alveoli.

Case 3. The last patient was a child 14 days old, admitted because she had refused to feed for the past two to three days. Clinical examination revealed the presence of a left diaphragmatic hernia, which was confirmed by radiographs (Fig. 4). Laparotomy was performed, and the stomach, small intestine, part of the colon and spleen had protruded into the left thorax through a large opening in the diaphragm. They were carefully pulled down. On opening the hernial sac the left lower lobe was found to be rather hypoplasic, but functioning well. On further examination of the left thorax, a small accessory pulmonary lobe-like mass in the posterior costo-diaphragmatic angle was seen. The consistency was that of atelectatic tissue but there was no connexion with the adjacent lung.

FIG. 4.—Case 3. Shows presence of diaphragmatic hernia on left.

Fig. 5 shows the presence of the eventration and its relationship to surrounding structures. Behind the hernial sac is the medial pedunculated accessory lung lobe, which contains an artery arising from the aorta. The mass was removed and the diaphragm was reconstructed by means of the hernial sac membrane. Uncomplicated post-operative progress was verified radiologically (Fig. 6). The child was completely cured.

Microscopical examination showed the presence of bronchi, bronchioles and normal respiratory epithelium.



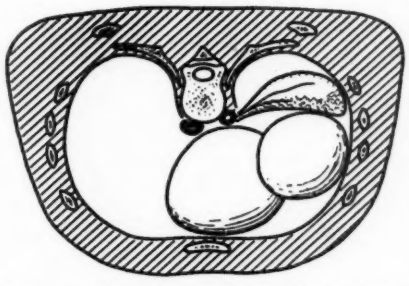


FIG. 5.—Case 3. Diagram showing relationship between diaphragm, hernial sac and accessory lobe.

There was extensive widening of many bronchi. Some groups of alveoli contained foam cells (Fig. 7).

Discussion

Many theories have been advanced about the pathogenesis of this anomaly. The 'traction theory' of Pryce (1946) seems to be the most acceptable. He states that the arterial component is the primary and the malformation of the pulmonary component is secondary. As a result of the persistence of an

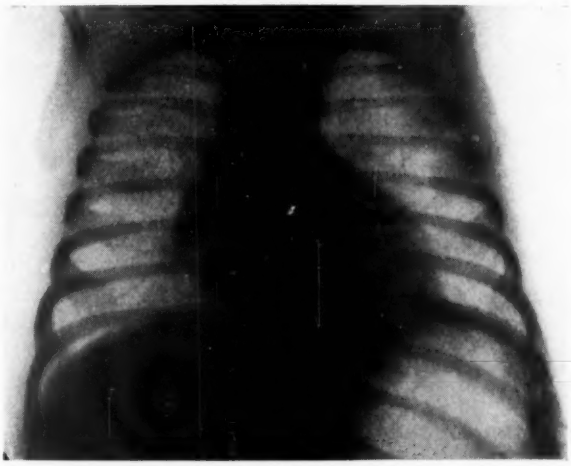


FIG. 6.—Case 3. Twenty-two days after operation.

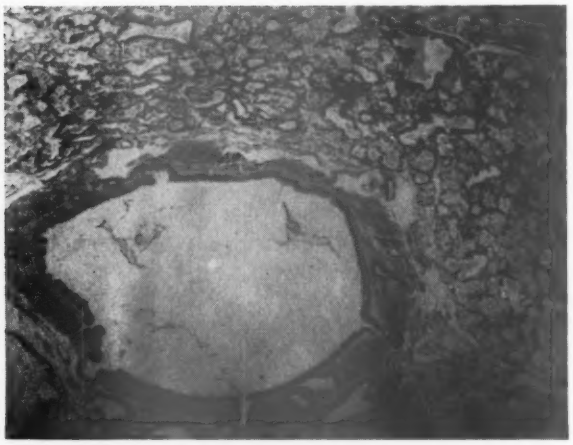


FIG. 7.—Case 3. Histological section showing bronchus, bronchioles and alveoli.

aberrant artery, which supplied a part of the primitive lung lobe, a vascular traction from this lung lobe occurs. The consequence is the dissociation of a piece of pulmonary tissue developed as a sequestration. On the other hand there is the 'fraction theory' which states that pulmonary sequestration develops by abnormal dissociation of a small primitive lung component which seeks an arterial supply from the visceral branch of the aorta itself.

Pulmonary sequestration is composed of respiratory epithelium and ramified bronchi or bronchiectasis without communication with the normal bronchial system. Intralobar sequestration occurs most often in the lower lobe, on the postero-medial aspect. The cases of Cohn and Hopeman (1955), and Warner *et al.* are the only exceptions, because these were found in the upper lobe. Extralobar sequestration is a completely dissociated or ectopic lobe, which can be found above or below the diaphragm. Only in the case of Gruber (1914) was the peduncle attached to the lateral thoracic wall.

The commonest location of extra-lobar sequestration is the left thoracic side and it is related to a diaphragmatic hernia, as in our third case. It is also found in the pericardium and in the abdomen. Location in the right side is rare. Associated anomalies are found, such as congenital absence of pericardium and communication with the oesophagus. Intralobar sequestration is predominant on the right side and has no relation to other congenital malformations.

With the exception of the complications there is no definite clinical feature of this condition. Sometimes there might be a history of chronic respiratory tract infection, such as productive cough, fever, pleuritic pain, etc. In only a few cases were the patients diagnosed pre-operatively. In most of them the sequestration was found accidentally on radiological examination or at operation. No typical feature appears on the radiograph. However, in a chest film which shows an opacity in the lower lobe and displacement of the bronchi with normal pulmonary findings, we should at least consider this condition. Bronchography is important in the diagnosis, but differentiation from a lung cyst or tumour is not easy. Only in a case of infected pulmonary sequestration can we perhaps see the communication between both bronchial systems on bronchography. Aortography has been suggested by some authors.

Infection of an intralobar sequestration is the commonest complication and is often found. The mode of infection is supposed to be haematogenous. Tuberculosis, malignant change and haemorrhage have also been reported.

The only treatment is operative extirpation of the sequestration. Most authors prefer lobectomy for the intralobar sequestration because removal of the sequestration alone is possible only in exceptional cases. After conservative operation the focus of infection remains in the lung and can spread at any time. Moreover, communication of both pulmonary and aberrant circulations after conservative operation has been observed and an A-V shunt should occur.

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HIATUS HERNIA IN CHILDHOOD*

BY

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The first description of a hiatus hernia was probably that of Bright (1836), who recorded the autopsy of a girl aged 19 years in whom a large portion of the stomach was in the chest and the cardia was at the level of the fourth dorsal vertebra. In the early part of the present century the condition was thought to be rare; Eppinger's (1911) series of 650 diaphragmatic herniae contained only 11 cases of hiatus hernia and in Quénu's (1920) series of 112 cases of diaphragmatic hernia treated surgically there were only two cases of hiatus hernia. With the introduction and development of radiology it was recognized (Åkerlund, 1926) that sliding hiatus hernia, in which the cardia and part of the stomach lie a varying distance above the diaphragm, is the most common form of diaphragmatic hernia and occurs frequently. The condition is found chiefly in the infant and in the middle-aged adult and it has generally been assumed that, in both age groups, similar factors are concerned in the aetiology and the mechanism of production of symptoms. There are, however, significant differences in the clinical features, the natural course of the disease and the response to treatment which suggest that, although the complications may be identical, hiatus hernia in the child is pathogenetically quite distinct from the majority of adult cases.

There is little doubt that infantile hiatus hernia is either present at, or develops shortly after birth; symptoms usually date from the first few days of life and the condition has been demonstrated radiologically during the first week. It was considered by Findlay and Kelly (1931) that hiatus hernia in the child is a congenital, developmental anomaly in which the oesophagus fails to lengthen synchronously with the caudal migration of the septum transversum so that the diaphragmatic hiatus comes to surround the stomach instead of the oesophagus. Botha (1958) thought that a large proportion of hiatus herniae is due to such a developmental short oesophagus. The rapid elongation of the oesophagus in the normal embryo occurs during the sixth and seventh weeks (Keith, 1948) and a gross anomaly occurring at such an early period of development would be expected to be accompanied frequently by other major abnormalities as is oesophageal atresia which arises about this time. The evidence concerning associated malformations with hiatus hernia is somewhat conflicting, but the reports of multiple anomalies, which include hiatus hernia, have been mostly of isolated cases or of small series (Williams, 1945; Radloff and King, 1947; Barrett, 1950). In our own clinical series of 76 cases no child has a known major congenital abnormality and a low incidence of associated lesions was found by Thomsen (1955) and by Bonham Carter (1956), although mental deficiency was not uncommon in their series.

The anatomical features of hiatus hernia in the child suggest that a developmental shortness of the oesophagus is an unlikely aetiological explanation. The almost invariable presence of a sliding peritoneal sac covering the anterior and left aspects of the intra-thoracic portion of the stomach, the fact that this part of the stomach derives its vascular supply from the coeliac axis and not from the thoracic aorta, and the operative finding that the vagi are not taut and, unless involved in peri-oesophageal fibrosis, do not interfere with reduction of the hernia appear to indicate that the cardia was originally in the abdomen and only later migrated into the chest. In the acquired hiatus hernia of the adult, in which the pathological anatomy is identical with that of the child, an important aetiological factor in most cases, and the primary one in many, is relaxation of the diaphragmatic hiatus due to degenerative changes in the musculature. Barrett (1954) and Forshall (1955) have therefore considered that the essential lesion in the infantile case is a congenital weakness or laxity of the hiatus which allows herniation of the cardia shortly after birth when a negative intra-thoracic pressure develops with the onset of respiration. An objection to this hypothesis is that hiatus hernia in the child can undergo gradual spontaneous reduction (Figs. 1 and 2) and eventual cure; spontaneous recovery of

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

FIG. 1.—Long, tubular hiatus hernia in child aged 3 months. Cardia at level of sixth dorsal vertebra.

FIG. 2.—Same patient as in Fig. 1, aged 18 months. Symptomless. Marked spontaneous reduction in size of hernia.

FIG. 3.—Autopsy specimen of hiatus hernia in still-born anencephalic infant. Forceps in sliding peritoneal sac.

FIG. 4.—Same specimen as in Fig. 3. Stomach and cardia withdrawn from above diaphragm, demonstrating sliding sac.

a diaphragmatic weakness, if possible at all, would be unlikely to lead to the reduction of a large hernia. The autopsy finding of a hiatus hernia in a still-born anencephalic infant indicates that a pressure difference between the abdomen and the thorax is not an essential pathogenetic factor. The gross associated anomaly in this case at first suggested that the condition was a 'congenital short oesophagus' but dissection revealed the typical anatomical features of a sliding hernia (Figs. 3 and 4). As the child had never breathed, the cardia must have become displaced during pre-natal life.

An important agent in the production and maintenance of some cases of adult hiatus hernia is pressure from below, displacing the cardia upwards through the hiatus; symptomatic and even radiological cure may follow reduction of intra-abdominal pressure by the elimination of obesity, the abandonment of corsets or the evacuation of a pregnant uterus (Dutton and Bland, 1953). There is no evidence of an unduly high intra-abdominal pressure in the infant with hiatus hernia but the not infrequent association with hypertrophic stenosis of the pylorus, the phreno-pyloric syndrome of Roviralta (1952), suggests that raised intra-gastric pressure or increased gastric peristalsis may similarly force the cardia into the chest. The coincidence of pyloric stenosis in our hiatus hernia series is 10·5%. In Bonham Carter's (1956) series of 136 cases of hiatus hernia five children had pyloric stenosis and he suggested that the vomiting caused by the latter leads to the development of the hernia when there is a congenital laxity of the oesophageal hiatus. In our eight patients with the double lesion, however, vomiting began shortly after birth and not, as occurs with pyloric obstruction alone, after the second week of life.

The pathogenesis of hypertrophic pyloric stenosis remains unknown. Thomson (1933) considered that the muscular hypertrophy of the pyloric canal occurs as a result of a preceding functional obstruction at the pyloric sphincter. Friesen, Boley and Miller (1956) claim to have demonstrated immaturity of ganglion cells in the pyloric tumour. As pyloric stenosis, unlike hiatus hernia, occurs predominantly in the male and has a high familial and hereditary incidence, there is obviously no all-embracing aetiological explanation for the two conditions but their frequent co-existence lends support to Thomsen's theory of a prenatal functional pyloric obstruction; the increase in intragastric pressure so produced may then lead to prolapse of the cardia into the chest especially since, at this period of development, the gastro-oesophageal junction is probably not yet stabilized in its normal position.

Some of the clinical features of infantile hiatus hernia, even when there is no associated hypertrophic pyloric stenosis, also suggest the presence of a gastric emptying disorder. That the hernia and the incompetent cardia, although responsible for the development of oesophagitis, are perhaps not the primary cause of the main symptom of vomiting is indicated by the fact that, in those children treated medically and in many of those treated surgically, the hernia and gastro-oesophageal reflux may still be demonstrable radiologically many months after vomiting has ceased. Interference with gastric emptying is suggested by the frequent clinical finding of visible gastric peristalsis and by the fact that the vomiting itself, unlike the passive postural reflux of a small quantity of gastric contents which occurs in the adult, is usually forcible or even projectile, of large volume and not immediately controlled by postural treatment.

Medical management of hiatus hernia in infancy is often successful in relieving the symptoms and in allowing spontaneous cure of the hernia and the development of a competent gastro-oesophageal sphincter. The disadvantage of conservative management is that hospital treatment must often be prolonged, and it is difficult to decide when the patient may be considered free of the risk of complications developing. It is often considered that cure has been achieved when vomiting ceases and the child gains weight normally. The hernia and the incompetent cardia persist, however, for some considerable time after vomiting has stopped and the symptomless patient may still be exposed to the risks of oesophagitis and its sequelae. Severe complications, if they are going to occur, usually develop early but this is not invariably the case; in one of our patients an oesophageal stricture first appeared at the age of 10 years (Figs. 5 and 6). Chronic penetrating ulcer of the intra-thoracic portion of the stomach (Barrett's ulcer) may also develop in later childhood (Fig. 7).

The conventional surgical procedure for hiatus hernia in the child, as in the adult, is transthoracic, transdiaphragmatic reduction of the hernia and repair of the enlarged oesophageal hiatus. In our experience of 40 cases this operation has not given satisfactory results; vomiting has persisted after operation in over 50% of patients and radiological examination, carried out one year or more after operation, has shown recurrence of the hernia or persistence of gastro-oesophageal reflux in over 70%. Unsatisfactory results of hiatal herniorrhaphy in childhood have also been recorded by Husfeldt (1953) and by Thomsen (1955).

Although there is no radiological confirmation of

FIG. 5.—Hiatus hernia without stricture in boy aged 6 years.

FIG. 6.—Same patient as in Fig. 5, aged 10 years. Severe oesophageal stricture.

a gastric emptying disorder in cases of infantile hiatus hernia, there would appear to be sufficient clinical evidence of its temporary presence, responsible at least in part for the development of the lesion and the production of the symptom of vomiting, to justify the therapeutic application of this hypothesis. The operation of pyloroplasty has therefore been applied to the treatment of hiatus hernia in childhood. The rationale of this procedure is that facilitation of gastric emptying will discourage

FIG. 7.—Operation specimen. Chronic penetrating peptic ulcer (Barrett's ulcer) of intra-thoracic part of stomach in boy aged 9 years with recurrent haematemesis.

vomiting and encourage spontaneous cure of the hernia and the development of a competent gastro-oesophageal sphincter. Peptic oesophagitis is due to reflux of pepsin and acid from the stomach; the most severe effects are probably produced by reflux of unbuffered gastric juices when the stomach is empty of food. In order to inhibit this neurogenic peptic secretion and so render inert fluid regurgitating into the oesophagus, bilateral vagotomy has been performed in addition to pyloroplasty when endoscopy revealed the presence of oesophagitis. These procedures have so far been applied to only a small series of cases. The early response has been satisfactory but more prolonged study of the patients is required before full assessment of the results is possible.

Summary

The pathogenesis of infantile hiatus hernia is discussed. It is considered that an important factor in the causation of the hernia and in the production of vomiting is a disorder of gastric emptying. The operation of pyloroplasty and, in the presence of peptic oesophagitis, vagotomy has therefore been carried out in a small series of cases.

I am grateful to my colleagues Miss Isabella Forshall and Mr. P. P. Rickham and to the paediatric physicians

of the Liverpool Region who have permitted me to examine their patients. I am indebted to Dr. E. G. Hall for the use of autopsy material.

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TEMPERATURE CHANGES DURING NEONATAL SURGERY*

BY

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My subject is temperature changes occurring during neonatal surgery. My interest in this subject was stimulated by the obvious cooling which occurred during neonatal operations, the absence in current practice at Great Ormond Street of any special measures to prevent this loss, and the varied methods of rewarming in practice. Also there occurred one or two cases of post-operative sclerema, and it seemed worth while to investigate this temperature loss more fully.

In the past six months or so I have recorded the temperatures, at 10-minute intervals, of 25 infants during operation. Temperatures have been recorded in all cases by a Thermocouple calibrated against an alcohol thermometer reading over the range 20-40° C. and the lead has in all cases been placed in the rectum, except on the two occasions when this would have interfered with the operation. An oesophageal lead was then used. The oesophageal temperature has usually been found, on the occasions when both readings have been taken, to be somewhat higher than the rectal, but the same rate of drop has occurred.

The infants are divided into two groups: in the first 14 the existing practice was followed, no measures being taken to prevent heat loss, and in the next 11 cases the limbs and trunk, apart from the operation site, were insulated with cotton wool held in position by crepe bandages. On later analysis of the type of operations performed it was found that these two groups could fairly be compared.

The average time of operation was 80 minutes and the average temperature loss in the control group was 2·31° C. and in the insulated group 1·56° C. (Table 1). The following are some graphic records of these infants, all of whom were less than 7 days old.

In the control group the greatest loss recorded was in a 6-day-old infant with a diaphragmatic hernia which was reduced through an abdominal approach. She had a good initial temperature and lost 4° C. in 100 minutes (Fig. 1).

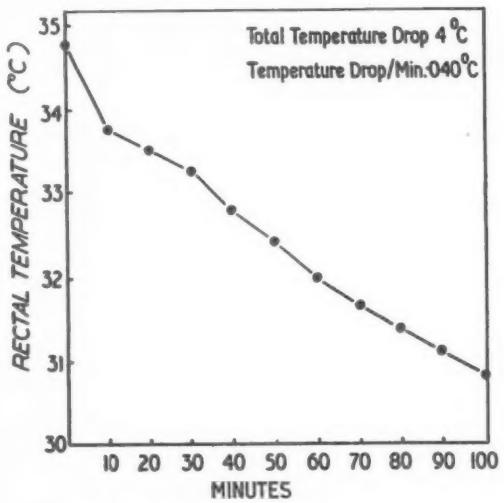

FIG. 1.—J.H., aged 6 days, birth weight 7 lb. 1 oz. Diagnosis: right diaphragmatic hernia.

A characteristic chart is shown in Fig. 2. This is an oesophageal temperature recording, as the baby was having a 'pull-through' operation for anorectal agenesis. There was quite a good initial temperature with a steady loss thereafter until the peritoneum was closed, when there was a slight elevation.

TABLE 1

NEONATAL TEMPERATURE LOSS
(TOTAL CASES RECORDED 25)

Group 1		Group 2	
Controls 14		Insulated 11	
Average temperature loss 2·31° C.		Average temperature loss 1·56° C.	
Average length of operation 80 mins.			

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

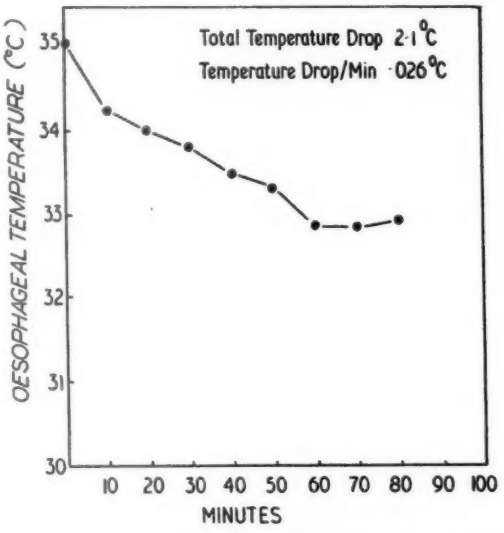

FIG. 2.—A.M., aged 12 hours, birth weight 6 lb. Diagnosis: anorectal agenesis.

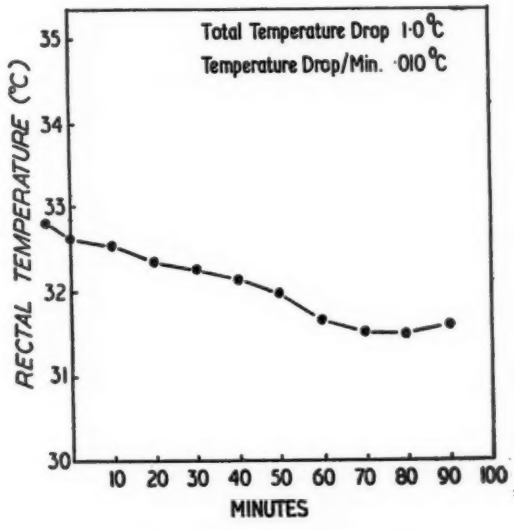

FIG. 4.—F.D., aged 3 days, birth weight 4 lb. 2 oz. Diagnosis: jejunal atresia.

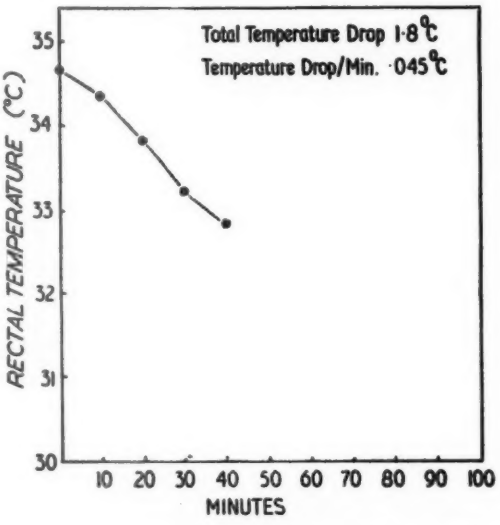

FIG. 3.—S.T., aged 1 day, birth weight 6 lb. Diagnosis: diaphragmatic hernia.

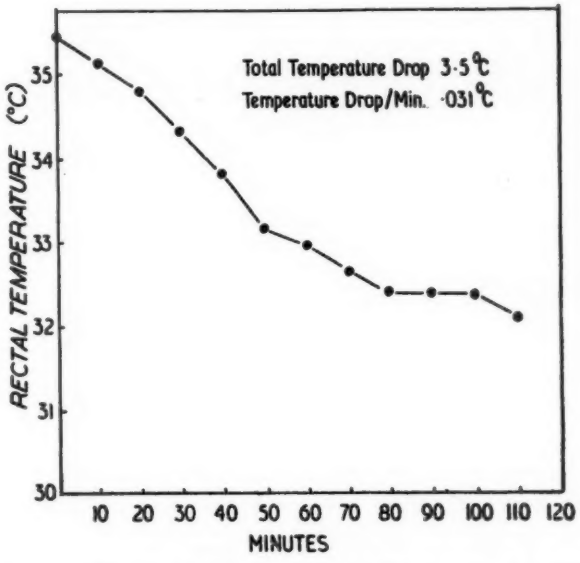

FIG. 5.—S.W., aged 5 days, birth weight 6 lb. 14 oz. Diagnosis: oesophageal atresia.

Fig. 3 is from another child with a diaphragmatic hernia which was again reduced through the abdomen, although rather more easily than in the first child. This chart shows well the marked and steady temperature drop, the loss being 1·8° C. in 40 minutes. Owing to the diminished differential between the temperature of the child and its environment, it was found, not surprisingly, that the lower the infant's initial temperature, the less the total drop, although the loss does continue (Fig. 4).

There were four cases of oesophageal atresia in the control group. Fig. 5 shows one of these. The temperature losses in these four cases were 1·7°C., 2·6° C., 2·6° C. and 3·5° C.

In the second group of cases, which were insulated, there were three cases of oesophageal atresia. Their temperature losses at operation were 1·6° C., 1·4° C. and 1·2° C., and the chart of one of them (Fig. 6) illustrates well the difference in rate of temperature loss. The operation here was rather

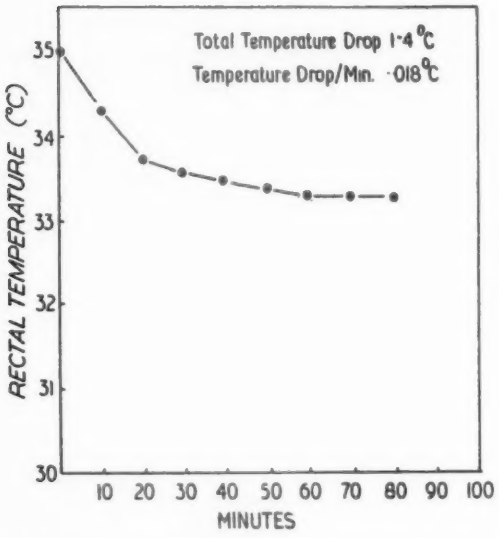

FIG. 6.—D.S., aged 18 hours, birth weight 6 lb. 3 oz. Diagnosis: oesophageal atresia.

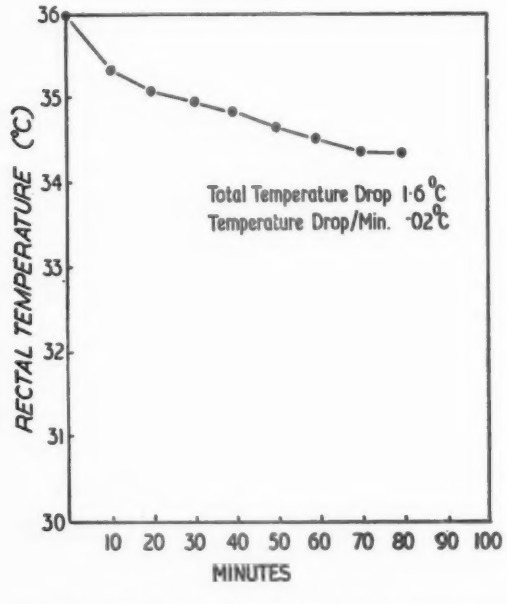

FIG. 7.—D.G., aged 3 days, birth weight 5 lb. 11 oz. Diagnosis: oesophageal atresia.

shorter than that of the previous case in the control group, but the temperature loss in 80 minutes was 1·4° C. whereas in the uninsulated child it was 3·2° C. in the same time.

A representative chart in the insulated group is of one of the other cases of oesophageal atresia (Fig. 7). This baby had a good initial temperature: there was the initial loss in the first 10 minutes and the loss thereafter was well controlled. Finally

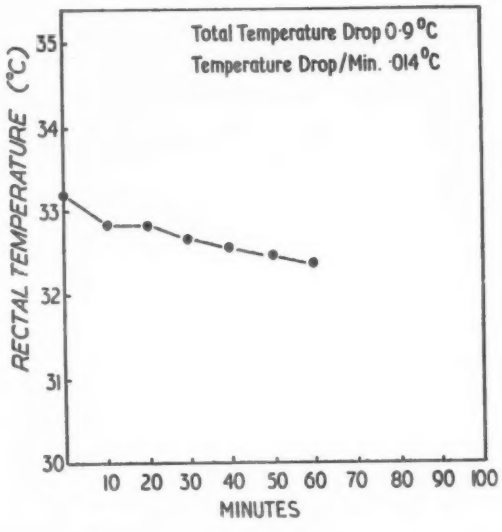

FIG. 8.—L.M., aged 2 days, birth weight 4 lb. Diagnosis: ileal atresia.

an impressive recommendation for insulation is the chart (Fig. 8) of a 4 lb. (1,800 g.) infant operated upon for ileal atresia. In 65 minutes the total temperature loss was only 0·9° C. The figures of all the recordings are shown in Figs. 9 and 10. In the control group the loss per operation averaged 2·31° C., or 0·033° C. per minute, and in the insulated group the average loss was 1·56° C. or 0·02° C. per minute.

Points which arose during these recordings were:

(1) In several cases there was a considerable temperature drop between the time the child was brought into the theatre and removed from the incubator and the time the operation was commenced. Such temperature loss can, and should be, avoided.

(2) The diathermy electrode pad used during these operations measured 10 × 7 cm. The lead plate is enclosed in a cover soaked in saline, and placed under the baby's sacrum. The size of this plate could safely be reduced if especial care were taken in applying the pad, which should be kept unbent; the use of electrode jelly might also help to diminish temperature loss.

(3) Records were taken during these operations of conditions in the theatre. The average theatre temperature was 24·5° C. (76° F.) with a range of 20-26·7° C.; the average relative humidity was only 50% with a range of 41-64%; the number of persons present in the theatre varied from a minimum of seven to a maximum of 17. The ventilation system during all but one of these operations was changing the theatre air 17 times an hour. A

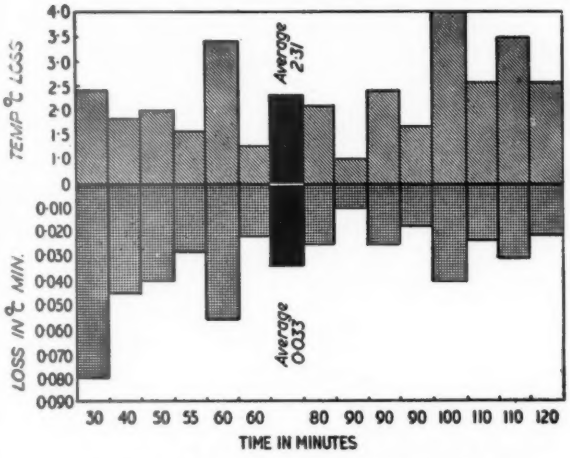

FIG. 9.—Figures of all the recordings in the control group.

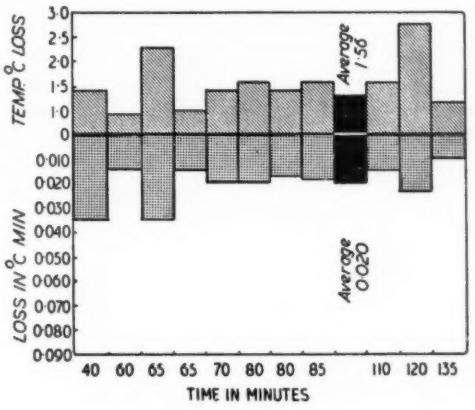

FIG. 10.—Figures of all the recordings in the insulated group.

higher environmental temperature and humidity will reduce heat loss and a temperature of 26·5° C. (80° F.) is not too unpleasant for the surgeon or theatre staff.

The question which, of course, arises is whether temperature loss in these newborn infants matters. Twenty-five cases is too small a series from which to draw any conclusions, but there was no significant difference noticed in the post-operative courses of the infants in these two groups. A vast amount of research has been undertaken of late into hypothermia and its effects, but I venture to suggest that the problem as referable to a newborn baby—and not infrequently a premature baby as well—is rather different from that in older children or adults. We take great care to maintain the temperature of our newborn babies post-operatively (at Great Ormond Street they are almost all nursed in incubators), and it seems irrational not to try to prevent heat loss at operation.

Silverman, Fertig and Berger (1958) reported the result of an investigation to determine the effect of temperature on the survival rates of premature infants. Their results confirmed the view that survival rates can be increased by reducing the heat loss of such infants in the first few days of life. Many neonatal surgical emergencies occur in premature infants, and for full-term infants it seems not unreasonable to suggest that heat conservation is also important. The more premature the infant the more inefficient is its temperature regulating mechanism; a normal baby also has a relatively immature regulating mechanism but after several days, perhaps a week, this mechanism has adapted itself to meet the needs of its new environment. The factors involved in this inability to regulate temperature are the immaturity of the centre itself—Brock called this 'lack of practice' (Ungeübheit); the inadequacy of the vasoconstriction and shivering mechanisms; and a relatively large surface area with a small amount of subcutaneous fat, both predisposing to excessive heat loss. On the heat production side it is worth mentioning that although the infant's basal metabolic rate is higher than the adult's, using body weight as a criterion, it is lower when estimated against surface area, and this is even more marked in the premature infant (Smith, 1951).

Rickham (1957) mentioned that in his series no active means were taken at operation to maintain the body temperature and listed three theoretical objections to heating the subject at operation, namely (*a*) that peripheral vasodilation may have the effect of depriving the vital centres of blood flow, (*b*) that a low temperature decreases the oxygen need by reducing the metabolic rate, and (*c*) that hypothermia increases neonatal resistance to anoxia.

Peripheral vasodilation is certainly undesirable and it should be remembered, in this context, that it is as easy to overheat an infant as to overcool it. I do not feel that the other two objections offer sufficient justification for allowing a large operative temperature drop.

A brief word about sclerema, the condition characterized by a yellowish-white skin which has a firm resistant feel, which does not pit on pressure and which is fixed to underlying bone and muscle. One case in this series developed the condition. This very ill baby had had a laparotomy elsewhere for intestinal obstruction. He was transferred to Great Ormond Street, was thought to have gastro-enteritis and possibly septicaemia in addition to his obstruction, and at re-operation required a colostomy for Hirschsprung's disease. He was treated with intravenous hydrocortisone immediately post-operatively

as a resuscitative measure. In spite of this he developed gross sclerema. The hydrocortisone was continued and he happily, and somewhat surprisingly, recovered. His initial temperature was 36·4° C. (97·5° F.), his limbs were padded and he lost only 1·4° C. during the operation. Excessive cooling does seem, from reports, to predispose to the development of sclerema, but it seems as if quite frequently, and possibly always, an infective process is involved also.

The conclusions which may be drawn from these investigations therefore are:

(1) Infants at operation may lose a considerable amount of heat. The full biochemical implications of this heat loss are at present unknown, but it is the opinion of one authority at least (Payne, 1959) that they are probably not very important. The effect on the infant's respiration is more immediately important and more easily appreciated. The hypothermia may appreciably delay the return of adequate respirations and predispose to post-operative chest complications.

(2) It is possible to reduce this temperature loss by one-third by the simple expedient of wrapping the infant in cotton wool. A higher theatre temperature than is customary has also been shown to diminish loss.

(3) In the latter part of this series, using insulation and a high environmental temperature, the total loss was reduced by 1°C.-1·4°C. in several cases.

(4) It seems that if these measures are adopted, active heating by hot water bottle or electric blanket, which has to be carefully controlled during operation, is probably unnecessary.

(5) In view of the expected temperature loss during operation an infant whose temperature is initially low, especially one suspected of having any degree of infection, should probably be warmed before operation is undertaken in order to diminish the risk of development of sclerema neonatorum.

I would like to thank Professor A. W. Wilkinson for the interest he has shown and the helpful criticism he has offered me, both during this investigation and in the preparation of this paper. My thanks are also due to Mr. G. Lythe, of The Hospital for Sick Children, for his help in preparing the figures in this paper.

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INCUBATOR FOR INFANTS UNDERGOING SURGERY*

BY

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For the last six years all infants operated upon in the Neonatal Surgical Unit at Alder Hey Children's Hospital have been nursed in incubators during the immediate pre- and post-operative period. The infants are nursed at a constant temperature of 85° F. (29·5° C.). Draughts and sudden changes in temperature are thus prevented and the infants can be nursed naked. The rate and type of respiration can be constantly watched, the abdomen can always be inspected and the child can move freely and unrestrained by clothing. If necessary he can be nursed in a definite concentration of oxygen, which is important in cases with pulmonary collapse, pneumonia or abdominal distension. The infants are nursed in an atmosphere of 100% humidity, which, in our experience, is the most important single factor in the prevention of post-operative pulmonary complications, as it liquifies the sticky pulmonary secretion, thus preventing blocking of the bronchi and pulmonary collapse (Rickham, 1957a).

It has been shown by O'Brien, Hansen and Smith (1954) that newborn infants nursed under the atmospheric conditions described above have an insensible water loss less than half that of infants nursed at room temperature and humidity. The high atmospheric humidity not only reduces water loss to a marked degree, but it also makes any metabolic balance studies which may be carried out much more accurate, since at a temperature of 88° F. (31° C.) and 100% humidity the daily water loss remains constant at 13·8 g. per kg. of body weight (Rickham, 1957b).

Nursing in incubators is even more important for premature infants undergoing surgery than for full term babies. Premature infants stand a fall in body temperature very badly and require to be nursed at incubator temperatures of between 90° and 95° F. (32° to 35° C.). Any marked drop in body temperature in premature infants undergoing surgery predisposes to sclerema, the development of which may prove fatal (Rickham, 1957c).

Experience gained in the nursing of surgical newborn babies during the last 10 years has shown that the incubators in use for premature infants in medical paediatric practice are not very suitable for newborn babies undergoing operations. These children should be brought to the operation table in an incubator and should after operation be lifted off the table and returned to the incubator. Procedures such as examinations, obtaining blood samples, setting up intravenous infusions, sucking out the pharynx, passing stomach tubes, endotracheal intubation and artificial respiration should be carried out in the incubator with the minimum disturbance of the infant. An incubator which is employed to transport babies to and from the operating theatre must be provided with oxygen supply and drip stands.

A number of infants admitted to the unit for operation have been submitted to balance studies necessitating careful intake and output estimations and accurate daily weighing. Considerable disturbance was caused to the babies by these investigations when ordinary incubators were in use.

It was decided to modify a standard incubator so that it would fulfil the requirements mentioned above. The Mark IV incubator made by Messrs. Oxygenaire, Ltd., London, was chosen for this purpose. The modified incubator has now been in use for several months and has proved very satisfactory.

The Mark IV incubator contains no electric motor, air circulation being produced by thermal convection. The absence of a motor eliminates many causes of mechanical breakdowns. Apart from the usual humidifying mechanism, a built-in atomizer (Fig. 1) permits the raising of the atmospheric humidity to 100% within a few minutes. Warm dry air circulates behind the front panel preventing misting due to humidity and allowing the infant to be watched at all times. Even with an oxygen inflow of 6 litres per minute the oxygen concentration in the incubator cannot rise above 35%; with the usual practice of allowing 1½ litres per minute, the concentration is 26%. There is a slight positive

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

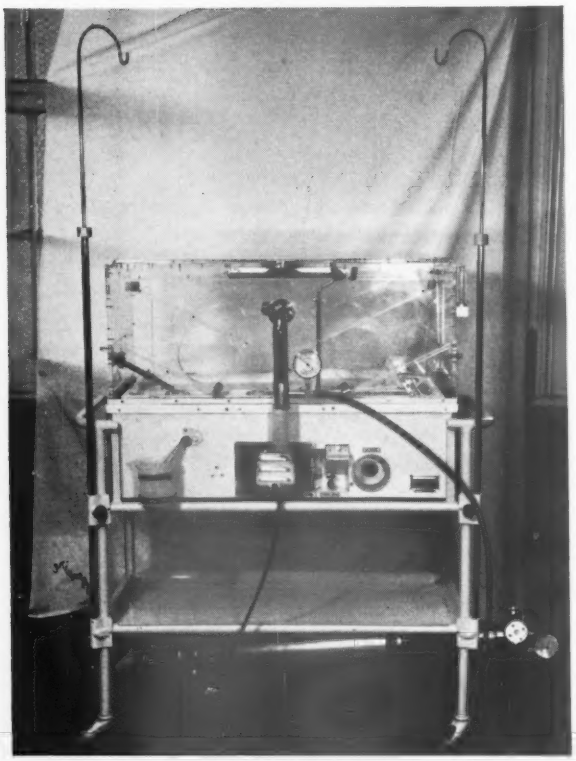

FIG. 1.—Rear view showing atomizer in centre and receptacle for urine on left side. Note adjustable drip stands and oxygen cylinder carrier.

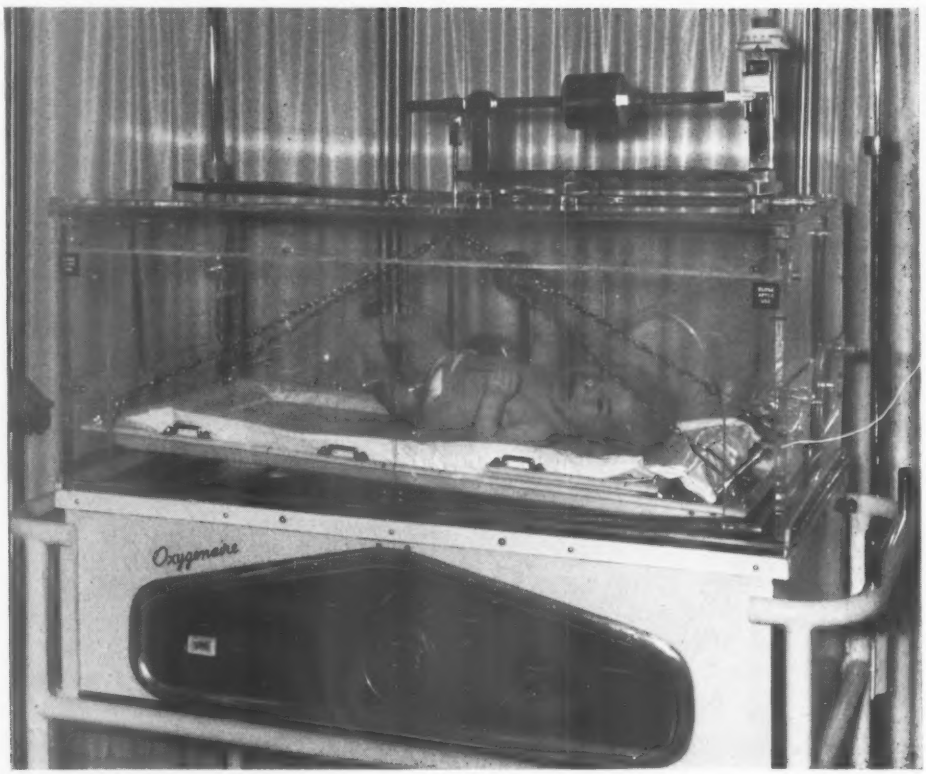

FIG. 2.—Front view showing large sliding doors. Plastic cradle is suspended from weighing machine. Note metal buckles at edge of plastic cradle.

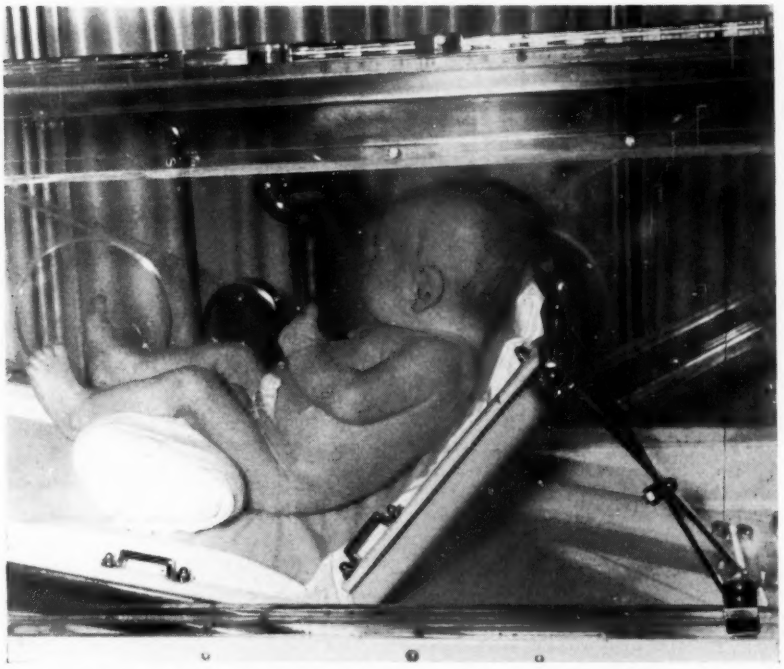

FIG. 3.—Infant nursed in semi-sitting position on adjustable backrest.

pressure in the incubator, so that opening it does not cause air to rush in.

In the modified surgical model the front panel is composed of two horizontally sliding doors, which when open give the widest possible access. The groove in which the sliding doors run is just below the level of the tray on which the infant lies so that the infant can be handled without discomfort to the nurse's arms.

The child is nursed on a plastic, radio-translucent cradle, which can be tilted into Trendelenburg's and anti-Trendelenburg's positions. Six metal buckles are fixed along the edge of the cradle and it is thus possible to immobilize the baby in various positions by tying the limbs to the buckles (Fig. 2). In order to nurse the infant in a semi-sitting position, which may be necessary for such conditions as hiatus hernia, an adjustable backrest is incorporated (Fig. 3). Radiographic pictures are taken by placing the photographic plate underneath the plastic cradle on a metal tray which can be pulled out through a hinged panel situated on the left side of the incubator. In order to facilitate accurate placing of the cassette beneath the infant, the metal tray is divided into numbered squares corresponding to numbers printed on the side of the plastic cradle. The cassette is fixed securely to the tray with the aid of a metal bar attached to two rubber suction pads (Fig. 4).

On the right side of the incubator there is a hinged panel 6 in. in height (Fig. 5). With this flap open, various procedures can be performed. On admission the infant is placed into the incubator with his feet pointing towards this panel. When an intravenous infusion is set up in the ankle the child's feet are pulled out of the incubator through this opening (Fig. 6).

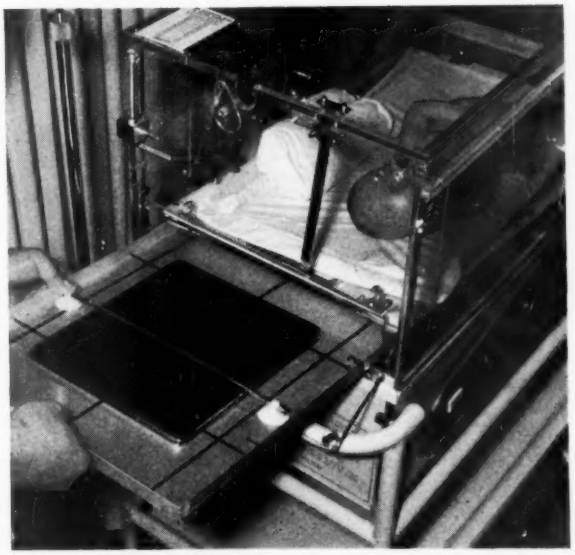

FIG. 4.—Left side panel. Metal tray pulled out and radiographic cassette fixed in position by metal band suction pads. Note drip feed apertures.

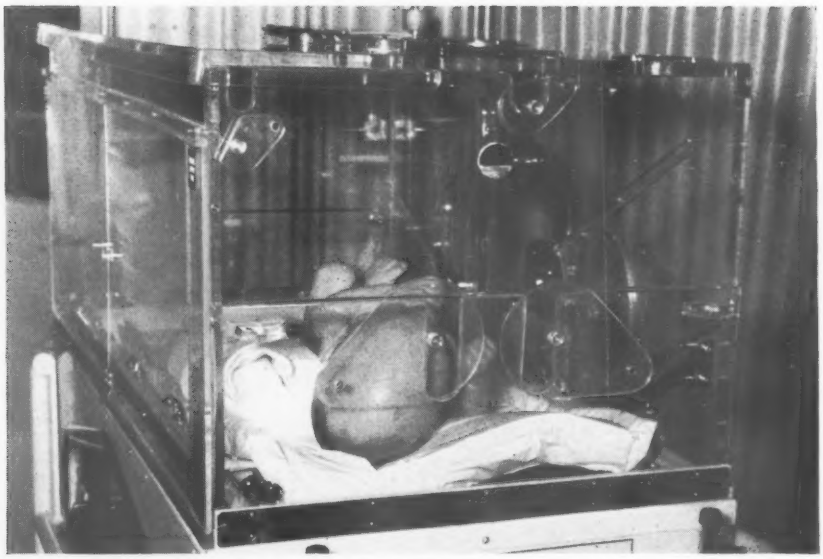

FIG. 5.—Right side panel showing large hinged flaps with deep slots guarded by plates cut into upper border.

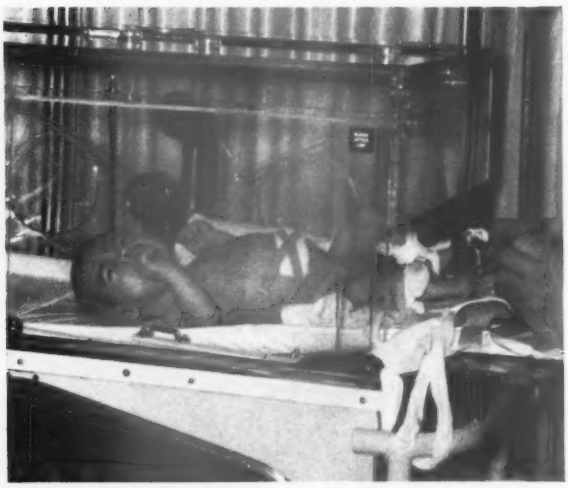

FIG. 6.—Intravenous infusion is set up in internal saphenous vein at right ankle.

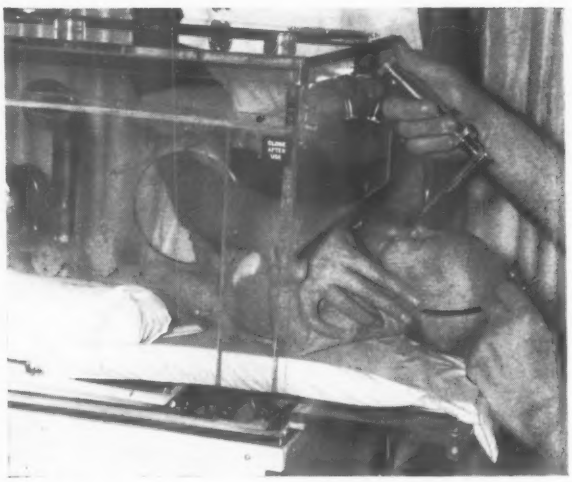

FIG. 7.—Endotracheal intubation.

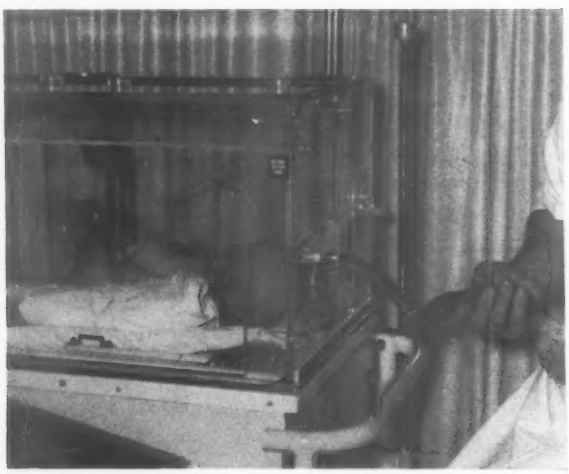

FIG. 8.—Artificial respiration given by endotracheal intubation.

Following the operation the infant is put back into the incubator with the head pointing towards the flap. Procedures such as emergency intubation (Fig. 7) and putting up of scalp vein infusions are thus easily carried out. Prolonged positive pressure artificial respiration is facilitated by passing the oxygen tubes through the deep slots cut into the hinged flap (Fig. 8).

There are four holes for suction drainage tubes along the lower edge of each side panel. The urine of male infants is collected by fixing a piece of Paul's tubing around the penis and passing it through an opening in the metal panel at the back of the incubator to a receiver.

The incubator is provided with two adjustable drip-stands fixed one to either side and an oxygen cylinder carrier slung beneath the bottom shelf (Fig. 1).

The infant can be weighed in the incubator without much disturbance by suspending the cradle on which he lies from an accurate weighing machine placed on top of the upper lid (Fig. 2).

We should like to record our thanks to Miss Isabella Forshall, Dr. J. G. Rees and Dr. A. L. Stead for their most helpful suggestions. The expert advice and generous help of Mr. S. Sullivan and Mr. F. Crosdail of Oxygenaire Ltd. have been invaluable in the planning of this incubator.

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DEVELOPMENTAL POSTERIOR ENTERIC REMNANTS AND SPINAL MALFORMATIONS*

THE SPLIT NOTOCHORD SYNDROME

BY

J. F. R. BENTLEY and J. R. SMITH

From the Royal Hospital for Sick Children, Glasgow

Clinicians have only recently recognized the aetiological factors that connect a wide variety of developmental anomalies of the skin of the back, the spine, the central nervous system and the gut (Beardmore and Wiglesworth, 1958; Nathan, 1959). Starting with the observations of Lereboullet (1863) on the formation of sagittally split embryos from artificially inseminated pike ova, evidence has slowly accumulated which shows their common origin from a single aberration of development.

The many publications in the intervening years dealing with these apparently dissociated malformations have been difficult to correlate, due to variations in both terminology and suggested aetiology. The purpose of this paper is: (i) To summarize the embryological background to the concept of the split notochord syndrome; (ii) to suggest a generic title for the group of anomalies and a nomenclature for the gut components; (iii) to describe five illustrative cases; and (iv) to give key references to the relevant literature.

The split notochord syndrome embodies lesions that have been described under the following titles:

> Anterior and combined spina bifida; 'butterfly vertebra'; diastematomyelia; diplomyelia; Klippel-Feil syndrome; accessory or persistent neurenteric canal; dorsal intestinal fistula; spinal and cranial cysts; post-vertebral 'teratomatous' or dermoid cysts and sinuses; pre-vertebral, mediastinal or mesenteric cysts; some enteric 'duplications' or diverticula; vesico-intestinal fissure and certain intestinal malrotations and diaphragmatic herniae.

Embryology

An embryo may develop with partial duplication and separation of the notochord, the level and extent of the separation being variable; this results in a gap developing in the dorsal tissue mass between the two parts of the notochord (Figs. 1 and 2). Through this gap the ventrally situated yolk sac or gut anlage endoderm will herniate and it eventually adheres to the dorsal ectoderm or skin anlage (Figs. 3 and 4). The hernia may rupture to produce a fistula from the yolk sac into the amniotic cavity which separates the halves of the future cord and spine (Fig. 5). Subsequent differential growth of the embryo tends to close and obliterate the fistula and the extent of residual lesions depends on the success attained by this process. Thus the development of the base of the skull, vertebral column and central nervous system may be affected as well as gut, while sequestration of dorsal ectoderm may lead to dorsal dermoid cysts and sinuses. Persisting remnants of yolk sac origin may differentiate into tissues characteristic of any part of the gut or its embryological derivatives such as lung, etc. (Figs. 6, 7, 8, 9). Differential growth of gut and vertebral column leads to wide separation of the areas affected in each, as in long diverticula originating within the abdomen and passing through abnormal openings in the diaphragm to a high thoracic vertebral attachment. Furthermore, abnormal fixation of gut to the vertebral column may cause subsequent failure of rotation.

Clinical Presentation

Hitherto all the consequent malformations have been considered individually as extreme rarities, but if they are grouped the basic pattern is found to be fairly common.

These malformations may be considered to fall into two broad classes: (*a*) visceral malformations, and (*b*) spinal and central nervous malformations.

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

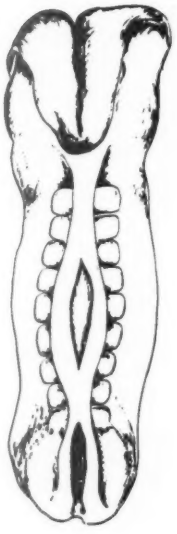

FIG. 1.—Anomalous embryo (2 mm.) with split notochord ('ring embryo').

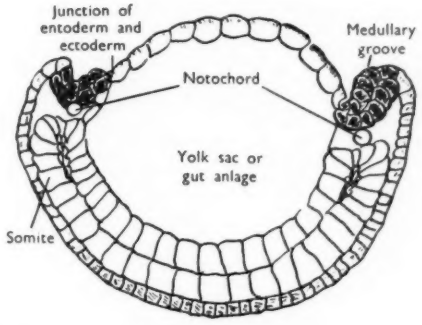

FIG. 2.—Section across anomalous embryo with split notochord.

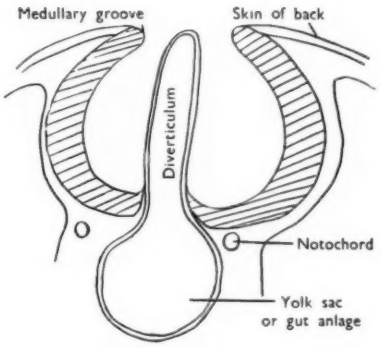

FIG. 3.—Posterior diverticulum of yolk sac developing between split elements of notochord.

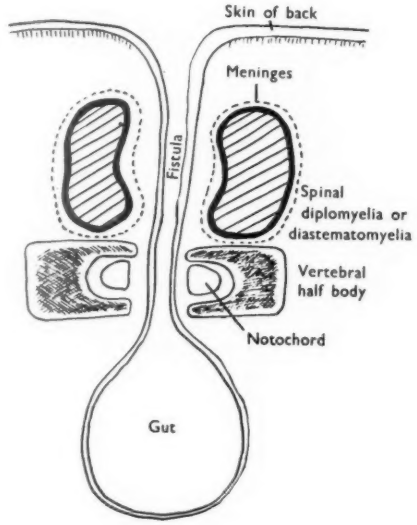

FIG. 4.—Early stage in evolution of developmental posterior enteric fistula.

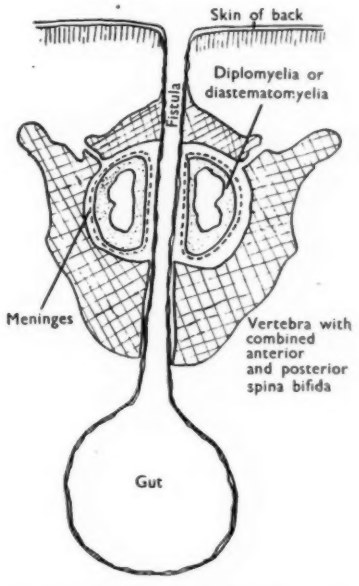

FIG. 5.—Established developmental posterior enteric fistula.

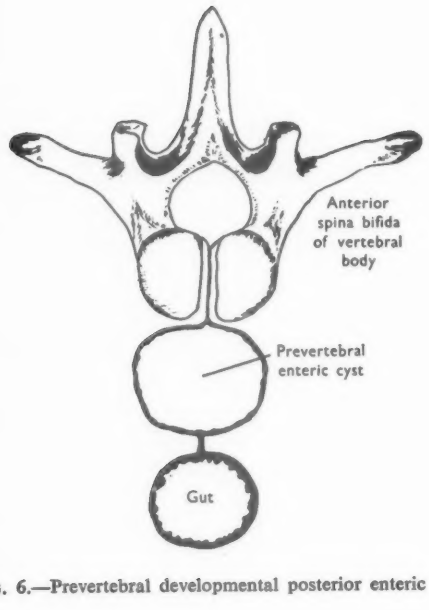

FIG. 6.—Prevertebral developmental posterior enteric cyst.

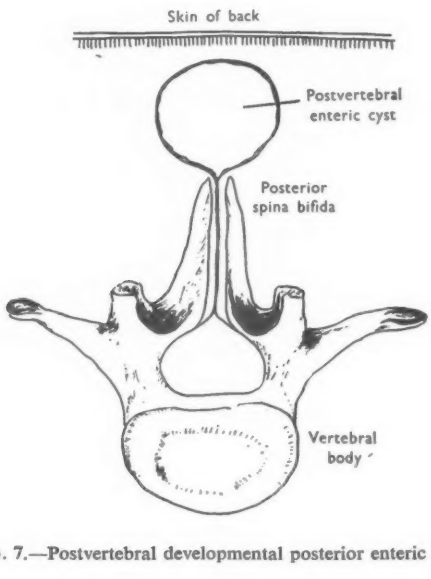

FIG. 7.—Postvertebral developmental posterior enteric cyst.

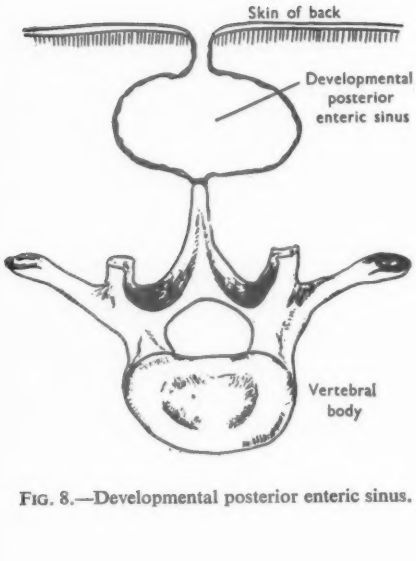

FIG. 8.—Developmental posterior enteric sinus.

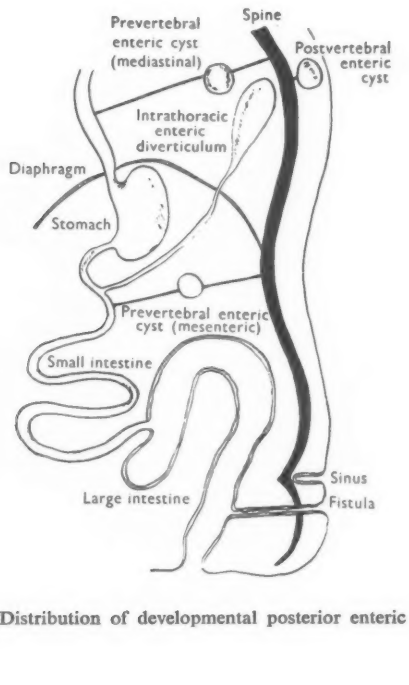

FIG. 9.—Distribution of developmental posterior enteric remnants.

(*a*) **Visceral Malformations.** The theoretical considerations accord well with the observed developmental anomalies classed in this paper as posterior enteric remnants. These may comprise certain mesenteric or posterior mediastinal 'duplications', diverticula or cysts connected by fibrous strands to the anterior aspect of the body of a vertebra situated cephalad to the enteric remnant. The vertebral body concerned is often bifid, and a complete anterior and posterior spina bifida occasionally exists.

Histological examination of the remnant will usually show the presence of smooth muscle and enteric mucosa in the walls of the lesion. The mucosal type may differ from that of the gut to which it lies adjacent, and it may be flattened and atrophic, the appearance giving no clue to its derivation. Occasionally broncho-pulmonary or other tissues primarily derived from the developing gut will be present.

The developmental posterior enteric remnants may be subdivided as follows:

(1) FISTULAE. When obliteration of the embryonic fistula fails completely the track passes back from the gut through the mesentery or mediastinum, traverses a complete spina bifida which may be coupled with a diastematomyelia or diplomyelia, to open on the skin in the midline of the back.

(2) SINUSES. The dorsal part of the embryonic fistula is all that persists. It forms a sinus derived from cutaneous or enteric tissues that passes forward from the midline of the skin of the back. There may be an underlying posterior or complete spina bifida.

(3) POSTERIOR ENTERIC DIVERTICULA. The ventral part of the embryonic fistula remains and communicates with the gut. There may be an associated anterior spina bifida or fibrous adhesion to a vertebral body.

(4) POSTERIOR ENTERIC CYSTS. Only an intermediate part of the embryonic fistula or diverticulum persists and the atrophic portions are represented by fibrous bands. These cysts may be prevertebral (posterior mediastinal or mesenteric), vertebral (spinal or mid-brain) or postvertebral in position. Many examples of the latter have been classed as teratomatous cysts. Anterior, combined or posterior spina bifida can be associated lesions.

Bremer (1952) proposed the term 'dorsal intestinal fistula' to cover this group of anomalies, a term we reject as so few of the lesions are true fistulae. The term 'enteric duplication' has also been applied to some of these lesions, causing confusion, as it should be restricted to anomalies attributable to defects of embryonic vacuolation of the gut, an entirely different process (Bremer, 1944).

Malformations of the heart and great vessels, oesophageal atresia and hiatus hernia have also been observed in association with defective spinal development. Whilst their coincidence is compatible with the theory of the split notochord, positive evidence is lacking.

(*b*) **Spinal and Central Nervous Malformations.** The gap in the dorsal tissue mass of the embryo, which is associated with a split notochord, may close without trace in the process of development. When this closure is less than complete the resultant spinal defect may range from a slight widening of the vertebrae to a complete anterior and posterior spina bifida. Minor degrees of anterior spina bifida produce the radiological appearance known as 'butterfly vertebrae', which may not be demonstrable without tomography. The more gross lesions may enclose enteric or cutaneous elements, as has been indicated. Pairs of hemivertebrae in these lesions may assume individual (if distorted) growth; fusion of the medial pedicles so formed results in the bony spur found with diastematomyelia (Fig. 10)

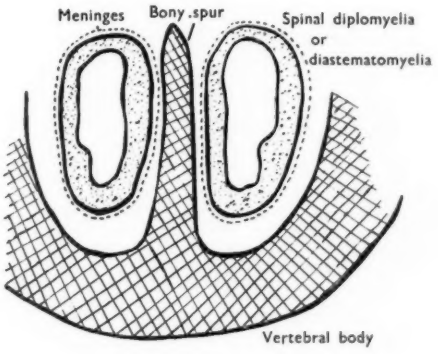

FIG. 10.—Diastematomyelia.

(Bremer, 1957). In this connexion it is noted that fusion of the cervical vertebrae constitutes the osseous element in the Klippel-Feil syndrome, and that these vertebral bodies are often split.

The spinal canal is widened in each of these types of vertebral modification, and anterior or posterior meningocoeles may protrude where the spine is bifid. When the spinal cord itself is cleft, the separated halves seldom rejoin inferiorly, possibly due to tethering by the nerve roots. Each half of the cord is invested in meninges derived from the spreading mesenchyme, and the two median walls of the dura and arachnoid may fuse to form a sheet of tissue

which contains any remnant of an enteric fistula. Within the meninges each half of the neural groove develops, either as the lateral half of a spinal cord (diastematomyelia) or as one of a pair of whole but malformed cords (diplomyelia) (Herren and Edwards 1940). During late foetal life the spinal cord migrates up the spinal canal and the injured segment becomes separated from the bony lesion, a process which can be limited by the anchor of a long bony spur. Matson, Woods, Campbell and Ingraham (1950) describe the clinical picture and the relief of symptoms consequent on excision of the spur.

The visceral, cutaneous, spinal and nervous lesions described so far in relative isolation may coincide in a variety of combinations, while hamartomatous malformation of the affected tissues not infrequently contributes to their bizarre nature.

Clinical Reports

Various manifestations of the split notochord syndrome within the chest and abdomen have frequently been described in detail under a variety of titles. There are fewer records of posterior enteric remnants situated within or behind the vertebral column, and five of these cases are therefore described. Three are personal cases, and the others were recognized in the library of recent clinical photographs. The number in no way reflects the total experience of the condition at the Royal Hospital for Sick Children, Glasgow.

Case 1. M.F. This girl was seen by Mr. Matthew White at the age of 11 years when she began to get attacks of pain in the left thigh precipitated by coughing. She had a limp and the left lower limb was ½ in. shorter than the right. A sinus 1 in. in diameter opened over the lumbo-sacral spine (Fig. 11); the surrounding tissues were tender but there was no neural deficit. Radiographs revealed a complete spina bifida of the lumbar spine and upper sacrum. A sinogram outlined the sinus to the laminae, and this part of the track was excised. The pathologist described it as a dermoid growth composed of skin elements and embryonic lung tissue. The lining was partly squamous epithelium in which were sebaceous glands and hair follicles. Adjacent were differentiated cartilage, embryonic bronchial cartilage and primitive lung tissues. The ciliated epithelium lining the bronchioles was supported by actively secreting mucous glands.

The sinus persisted but the girl remained well for four years, then being admitted to the Orthopaedic Unit, Western Infirmary (Mr. R. Barnes) with severe left sciatica of two weeks' duration. She was toxic and febrile to 102° F. with a fluctuant swelling above the sinus. She responded to treatment with sulphadiazine; penicillin and achromycin were ineffective.

FIG. 11.—Case 1. Developmental posterior enteric sinus.

FIG. 12.—Case 1. Cysternal myelogram consistent with diastematomyelia.

Subsequent investigations included a cysternal myelogram. The contrast medium ran down to the lumbar lesion and outlined both sides of a solid swelling 'within the canal' (Fig. 12). Stereoscopic studies revealed a flake of bone consistent with diastematomyelia in the upper lumbar spine. The cerebrospinal fluid was normal (Lange negative, protein 30 mg. %, sugar 50 mg. %, chlorides 714 mg. %).

After three and a half months' bed rest the child was discharged symptom free, only to be readmitted 10 months later for a further two months because of recurrent left sciatica. She was again pyrexial and toxic with a diffuse, tender, non-fluctant swelling of the left thigh and buttock extending to the lumbo-sacral area. The leucocyte count was 25,000 c.mm., the urine was normal and a blood culture proved sterile. The left femoral radiograph was normal. Urgent exploration of the left thigh opened an abscess deep to the tensor fasciae latae, yielding two and a half pints of pus from which coliform organisms were cultured.

She received tetracycline and responded well, but sinuses intermittently discharged from the left thigh and lumbo-sacral skin. This persisted for 10 months after she left hospital and she was therefore readmitted. Secondary infection with penicillin-sensitive *Staphylococcus aureus* had now occurred, the sinuses following the course of the previous abscess cavity. Healing was not promoted by systemic penicillin, so local instillation of chloramphenicol was tried. After treatment for one month an abscess reformed from the spinal defect and again *Escherichia coli* was isolated from the pus. Further drainage and chloramphenicol instillations sterilized the cavity, leaving a chronic sinus. After eight months in hospital, treatment was continued in the out-patient department and healing has slowly occurred.

Case 2. O.C. This girl was admitted under the care of Mr. Andrew Laird four days after premature birth with a gross malformation of the back. Bowel herniated extensively through the centre of the lumbo-sacral region forming a 'prolapsed natural colostomy' with exposed intestinal mucosa. The stoma was at the lower part of the prolapse and through it a catheter was passed into a prolapsed rectum (Fig. 13). Radiographs of the spine show duplication below the second lumbar vertebra and prolapse of gut backwards through the spinal defect (Figs. 14 and 15). Active treatment was not attempted and the infant died at home after eight days in hospital.

Case 3. F.McL. This boy was admitted to Mr. Dennison's wards at the age of 4 weeks. A hemispherical swelling 1 in. in diameter protruded in the midline over the upper sacrum. The basal two-thirds of the swelling were covered by normal skin and the apical third with mucous membrane which showed intermittent waves of peristalsis. In the centre mucus exuded from the orifice of a sinus (Fig. 16). This 7 lb. 6 oz. infant appeared normal in all other respects, including radiographs of the spine and barium studies of the gut, apart from a skin dimple below the lesion.

The lesion was excised together with the skin dimple, to which a narrow fibrous pedicle arose from the sacral hiatus. Healing was uncomplicated.

The excised ellipse of skin measured $3 \times 2 \cdot 5$ cm. and its centre looked like an enterostomy stoma from which a sinus penetrated just short of the deep surface of the specimen. Microscopy showed the skin to become continuous with a blind pouch of small intestine complete in all its layers. There was no evidence of meningocoele (Fig. 17).

FIG. 13

FIG. 14

FIG. 15

FIGS. 13 to 15.—Case 2. Developmental posterior enteric fistula. Radiographs of spine. Complete spina bifida.

FIG. 16.—Case 3. Developmental posterior enteric sinus.

FIG. 17.—Case 3. Microscopic appearance of excised sinus.

Case 4. A.G. This 6 lb. 1 oz, girl was admitted to Mr. Dennison's wards within 24 hours of her birth at term. Her general health was good, but a meningocoele 3·5 cm. in diameter covered by thin intact skin arose from the lower thoracic spine. Beneath the sac was an umbilicated red area 1 cm. in diameter, which had a smooth moist surface changing abruptly to normal skin at the periphery. The umbilication twitched slightly coincident with inspiration, and a probe was passed to 7 mm. An ill-defined soft swelling 2·5 cm. in diameter, covered by normal skin and with a bony spur palpable in its depths, extended on each side of the red area from below (Fig. 18a). A lower dorsal combined spina bifida was shown radiographically (Fig. 18b).

On the third day the meningocoele was excised with ligation of a narrow pedicle. The umbilicated lesion was found to be flanked by loose fatty tissue resembling infantile omentum but containing some muscle. The inspiratory retraction of the red dimple ceased when it was isolated to its pedicle, which emerged from an orifice, incomplete above, in the apex of a cone of fused spinous processes. The lesion was excised without removal of bone or exposure of the spinal cord. The child was discharged well and healed on the twenty-fifth post-operative day.

Microscopy confirmed the absence of nerve tissue in the meningocoele. The umbilicated area was covered by poor squamous epithelium, ulcerated in places. The track penetrating the deeper tissues was lined partly by squamous and partly by respiratory epithelium, and mucous glands were present in the wall. No smooth muscle was seen, but striated muscle and cartilage were in close proximity. The skin around the lesion showed an excess of the normal appendages in the dermis (Fig. 19).

Case 5. M.G. This 8½ lb. boy was admitted 24 hours after a normal birth at term. In addition to exstrophy of the bladder he had intestinal obstruction due to anal agenesis. His rudimentary scrotum was bifid and the testes were undescended. The two halves of the pelvis were separated not only anteriorly but also posteriorly where the sacrum was bifid. Projecting backwards from the apex of the sacral cleft was a bony spur entering a globular mass of tissue covered by skin bearing small flat haemangiomatous areas. A bulging smooth red membrane occupied the lower part of the cleft, and a small meningocoele arose from above the bony spur. Limited active movement was seen in the lower limbs (Fig. 20).

Treatment was limited to excision of the meningocoele with the bony spur and tissue mass, and left iliac colostomy under local anaesthesia. Chromosomal sexing was established from buccal smears. Although the child appeared to thrive he died suddenly and unexpectedly on the tenth day.

No specific cause of death was apparent at autopsy, which demonstrated the additional presence of a mild hydrocephalus without Arnold-Chiari malformation. The rectum was found to be a blind pouch passing back between the ureters to form the bulging membrane that occupied the lower part of the sacral cleft, and this membrane was covered on both its surfaces with intestinal mucosa (Fig. 21). The tissue mass excised at operation proved to be a teratomatous dermoid containing a developing tooth.

IG. 18a.—Case 4. Developmental posterior enteric sinus.

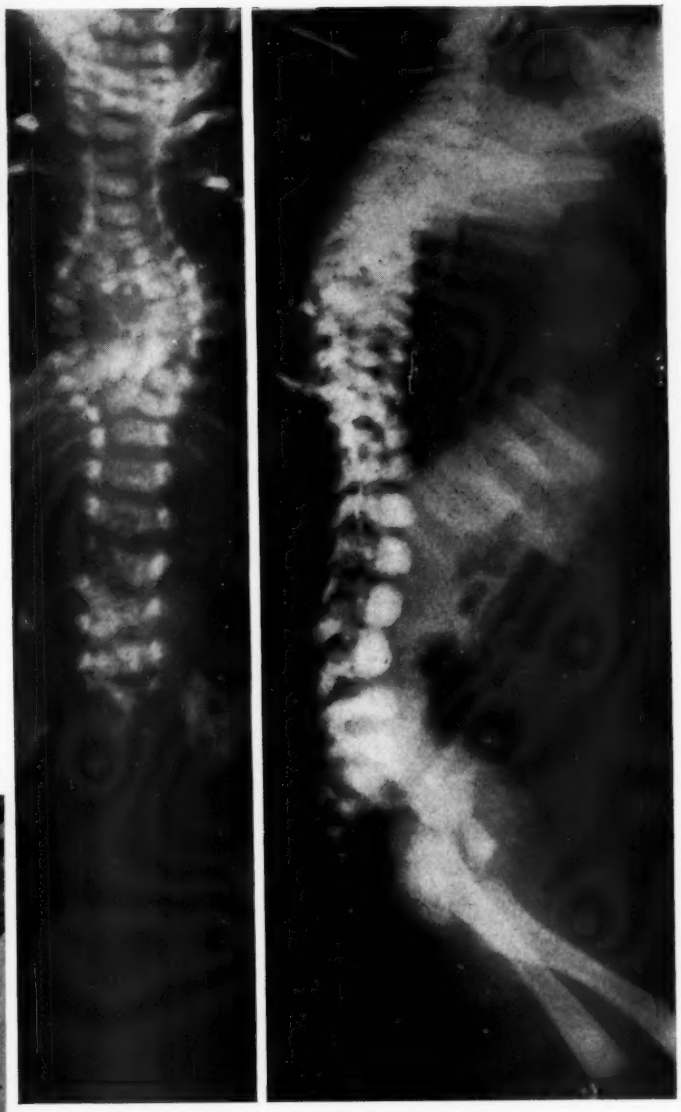

FIG. 18b.—Case 4. Radiographs of spine.

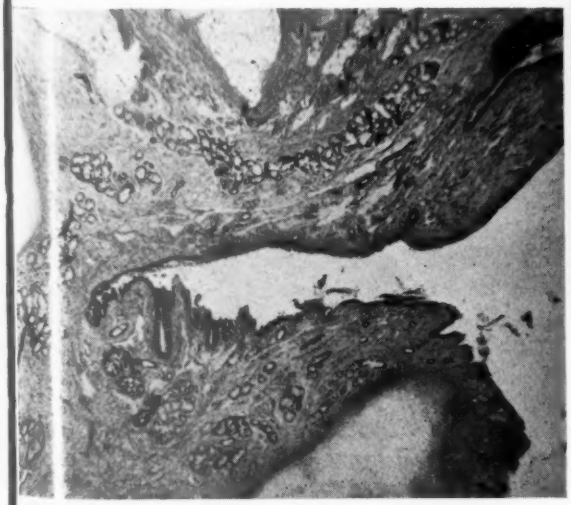

FIG. 19.—Case 4. Microscopic appearance of excised sinus.

FIG. 20.—Case 5. Developmental posterior enteric sinus with meningocoele, dorsal teratomatous dermoid and exstrophy of bladder (vesico-intestinal fissure).

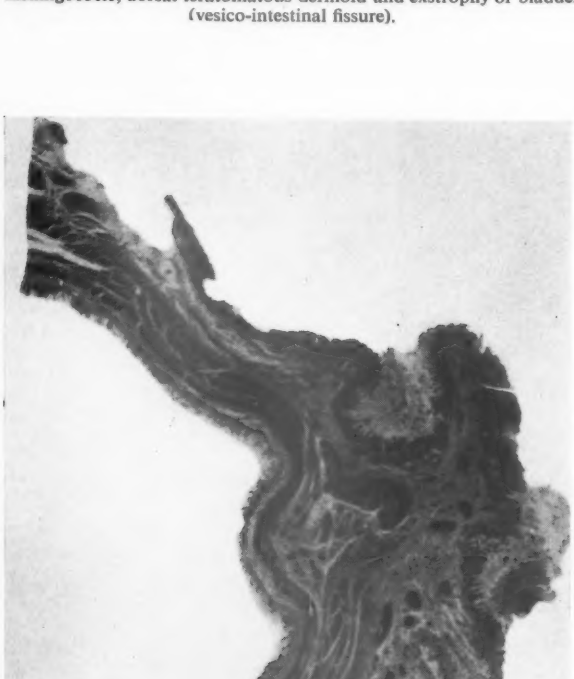

FIG. 21.—Case 5. Microscopic appearance of membrane lying in sacral cleft.

Case Commentary

The first patient is exceptional in having reached the age of 18 years in relatively good general health. In addition to her combined anterior and posterior spina bifida, diastematomyelia with a bony spur and splitting of the meninges investing the spinal cord have been demonstrated. The pulmonary tissues in the excised sinus have shown potentialities comparable with the foetal fore gut, whilst the repeated coliform infections which followed the partial excision raise the possibility of a tiny fistulous connexion with the gut. The second patient is an uncommonly gross example of a fistula from the hind gut. Peristaltic activity in the third case is remarkable, the enteric sinus lacking any residual connexion with the gut. The fourth case may be contrasted; here muscle contraction coincided with inspiration, suggesting that an abnormal branch from a phrenic nerve activated the striated muscle in a remnant which remotely caricatured bronchial elements. The fifth patient has a form of vesico-intestinal fissure (Hall, McCandless and Rickham, 1953) showing a dorsal teratomatous dermoid in association with posterior enteric diverticulum. The existence of intestinal mucosa on both surfaces of the terminal membrane of the diverticulum is consistent with it having been formed by the process of pinching off an embryonic fistula. The defects in the perineum and lower abdominal wall are consistent with a linear midline cleft of the caudal end of the embryo and modern concepts of the aetiology of exstrophy of the bladder (Glenister, 1958).

Discussion

The researches of Lereboullet (1863) on the effects of artificial insemination on the ova of the pike showed some of the resultant embryos to be split sagittally between a normal head and tail, the yolk sac being exposed centrally in the dorsal gap. By destruction of the first daughter cell of the frog ovum Roux (1888) produced embryos which were split but incomplete, but it was Hertwig (1892) who showed the production of true 'ring embryos' in the frog by fertilization of post-mature ova; he accepted the dorsal clefts as a variation of the neurenteric canal or blastopore, appreciated their role in the production of combined spina bifida, and coined the word diastematomyelia. Similar changes have been produced in mammalian embryos (Warkanay, 1960),

Oehlecker (1909) emphasized that the commoner variety of posterior spina bifida is the result of a separate and distinct anomaly occurring much later in foetal life, but where there has been a complete spina bifida anterior fusion and repair leaves a

persisting posterior defect. With both varieties of spina bifida there may be hamartomatous changes in the overlying tissues, often classified as teratomata (Nicholson, 1937).

Svitzer (1839) claims the first clinical description of combined spina bifida, the anterior cleft of which was traversed by coils of gut, and Muscatello (1894) reviewed a number of comparable cases. Lucksch (1903) described a still-born infant with an intestinal fistula traversing an upper dorsal spinal defect, and Keen and Coplin (1906) reported a patient with a congenital rectal fistula of bronchial structure that passed through the sacrum and cauda equina to open on the skin of the back. The Committee on Spina Bifida, Clinical Society of London, in their Report (1885), recognized that duplication of the centre of vertebral bodies could be associated with bony spurs dividing the spinal cord.

The modern concepts which link the observations on animal embryos with the clinical findings in man have been developed mainly by Saunders (1943), who more recently extended his theory jointly with McLetchie, Purves and Saunders (1954). Very similar conclusions were reached independently by Bremer (1952) and the introductory outline of this paper is based on the work of these authors.

Hertwig's theory that complete vertebral clefts are due to arrest of the normal fusion of the blastopore lips laid the foundations of discussion. The views of Budde (1912, 1926), Adelmann (1920), Gruber (1923, 1926) and Bell (1923) included speculation on the applicability of this theory to mammals. Gruber (1926) estimated the time of development of the anomaly and the role of mechanical compression, and Budde (1926) suggested that persistence of the primitive streak could provide an abnormal ento-ectodermal connexion.

Discounting Hertwig's theory, Feller and Sternberg (1929) suggested that a cell rest from the primitive knot (Hensen's node) persists and causes a cleft notochord; Korff (1937) further postulated proliferation of the cell rest to form an abnormal organ. These workers were the first to draw attention to the importance of the cleft notochord, an anomaly seen in human embryos by Johnston (1931) and Frazer (1931). The migration of the primitive knot with growth discounts the possibility of its derivatives splitting the notochord. The knot lies in the blastopore lip of the normal neurenteric canal, a minute tube which exists for a brief period connecting yolk sac and amniotic cavity; subsequent embryonic growth and development are such that the remains lie finally at the tip of the coccyx, caudal to any spinal lesion. For this reason Bremer (loc. cit.) avers that the lesion in the 'ring embryo' is an 'accessory neurenteric canal' and a perversion rather than an arrest of normal development.

An alternative theory proposed by Fallon, Gordon and Lendrum (1954) postulates an upset in the normal process of excalation of the notochord, which occurs in the third week of foetal life (Keith, 1948). They were influenced by the work of Stoeckel (1935) and Veeneklaas (1952), who noted the intimate contact of the endoderm with the notochord in early foetal life, and by the description by Patten (1946) of a 6-mm. human embryo with local kinking and fusion of the notochord to the neural tube. One of the authors has since abandoned this conception of the embryology in favour of that of Saunders (Lendrum, 1958).

Saunders (loc. cit.) has emphasized that anterior or combined spina bifida most frequently involves the cervical and cervico-dorsal vertebrae and many affected infants are still-born with skull defects or anencephaly; stomodeal duplication occurs occasionally (Morton, 1957). As the cephalic end of the notochord develops first this is in accordance with the theory of Stockard (1921) that an organ is most sensitive to disturbances in development at its moment of inception.

Summary

Evidence is presented that an abnormal splitting of the notochord, known to occur in the developing embryo, can cause a wide variety of malformations. These may involve the viscera of the chest or abdomen and incorporate abnormal tissue remnants of enteric derivation; they include combined spina bifida and allied vertebral malformations, together with associated central nervous anomalies and defects in the development of the skin and subcutaneous tissues of the back.

Hitherto these malformations have been individually named; it is now suggested that they can be usefully classified together as manifestations of the 'split notochord syndrome'. Their apparent rarity has been due to failure to appreciate the common basic aetiology.

A terminology is suggested for the abnormal structures of enteric origin in this group. They are classed as developmental posterior enteric remnants, be they fistulae, sinuses, diverticula or cysts.

Five illustrative cases displaying these enteric remnants are described.

Our thanks are due to Mr. Matthew White, Mr. A. P. Laird, Mr. W. M. Dennison and Mr. T. B. Gardiner for their help with clinical details of their patients. We are most grateful to Dr. Norma Macfarlane who prepared the line drawings and to Mr. J. A. L. Evatt, Mr. J. R. Devlin and Mr. W. B. Mason for their photography.

We also thank Dr. A. M. Macdonald for his great assistance with the details of histology. The preparation of this paper was undertaken whilst one of us (J.F.R.B.) was a research student in the Department of Child Health of the University of Glasgow.

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ACCESSORY ENTERIC FORMATIONS

A CLASSIFICATION AND NOMENCLATURE

BY

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There is considerable confusion in the present classification and nomenclature of accessory enteric formations—enterogenous cyst, archenteric cyst, gastro-thoracic cyst, duplication, etc. The purpose of this paper is to present a practical classification founded on the basic embryological deviations and a systematic nomenclature. Many of the anomalies are of some rarity and few surgeons are likely to acquire a series of any great size. The frequency of diagnosis should increase with an awareness of the types and the use of a common terminology.

The proposed classification is:

1. Duplications
2. Vitelline remnants
3. Dorsal enteric remnants

All have a typical enteric structure of smooth muscle and epithelial lining, not necessarily that of gut, to which it lies adjacent or from which it originates. In the third group the structure may be not of gut but of a gut derivative.

Classification

1. Duplications. This term should be restricted to these formations, either tubular or spherical, which lie in contiguity with normal bowel and which share with it a common blood supply and usually a common muscle coat. There may or may not be communication between the normal and anomalous lumina, and the dividing septum may be muscular or merely a double layer of epithelium.

During early foetal life, embryo and gut grow at a similar rate, a rate which soon becomes inadequate for the latter if the necessary absorptive area is to be provided. Accordingly, the rate of growth of the gut accelerates with thickening of the epithelial lining and obliteration of the lumen and subsequent recanalization by the coalescence of vacuoles which appear within the epithelium (Johnson, 1910). Coalescence of an additional group of vacuoles, which fail to rupture into the normal lumen, causes the formation of duplications, spherical or tubular, depending on the length of bowel affected.

2. Vitelline Remnants. Remnants of vitello-intestinal origin are included in the classification because firstly they are accessory enteric formations, secondly there are aetiological similarities to dorsal fistula, and thirdly there is a similarity in the two groups of remnants found after birth. There is little justification other than usage for perpetuating the present names of Meckel's diverticulum, entero-cystoma, enteroteratoma, raspberry tumour, etc.

Such remnants represent failure of closure of the vitello-intestinal duct. The mid-gut is in free communication with the definitive yolk-sac until the late pre-somite stage when the communication narrows to form the vitello-intestinal duct which in turn disappears by the end of the sixth week of foetal life. Incomplete obliteration gives rise to the anomalies shown in Fig. 1, which I suggest be called vitelline fistula, sinus, cyst and diverticulum. Similarly, I propose that an obliterated vitelline artery be called a vitelline cord.

3. Dorsal Fistula Remnants. During the second half of the nineteenth century, it was shown experimentally that sagittal clefts could be produced in frog and pike embryos with dorsal protrusion of the yolk-sac (Lereboullet, 1863; Roux, 1888; Hertwig, 1892). Bremer (1952) has suggested a similar occurrence during early human development with rupture of the yolk-sac herniation and formation of a fistula between yolk-sac and amniotic cavities, while Saunders (1943) and McLetchie, Purves and Saunders (1954) have postulated that a cleft notochord leads to adhesion of yolk-sac endoderm to ectoderm with subsequent erosion and fistula formation. However, during that phase of normal development when the notochord becomes intercalated in yolk-sac endoderm, openings appear in the floor of the notochord canal, thus establishing temporary communication between yolk-sac and amniotic cavities. Whatever the precise mechanism, it must be assumed that at some phase of pre-somite development such a fistula occurs. The development and obliteration of the vitello-intestinal duct is

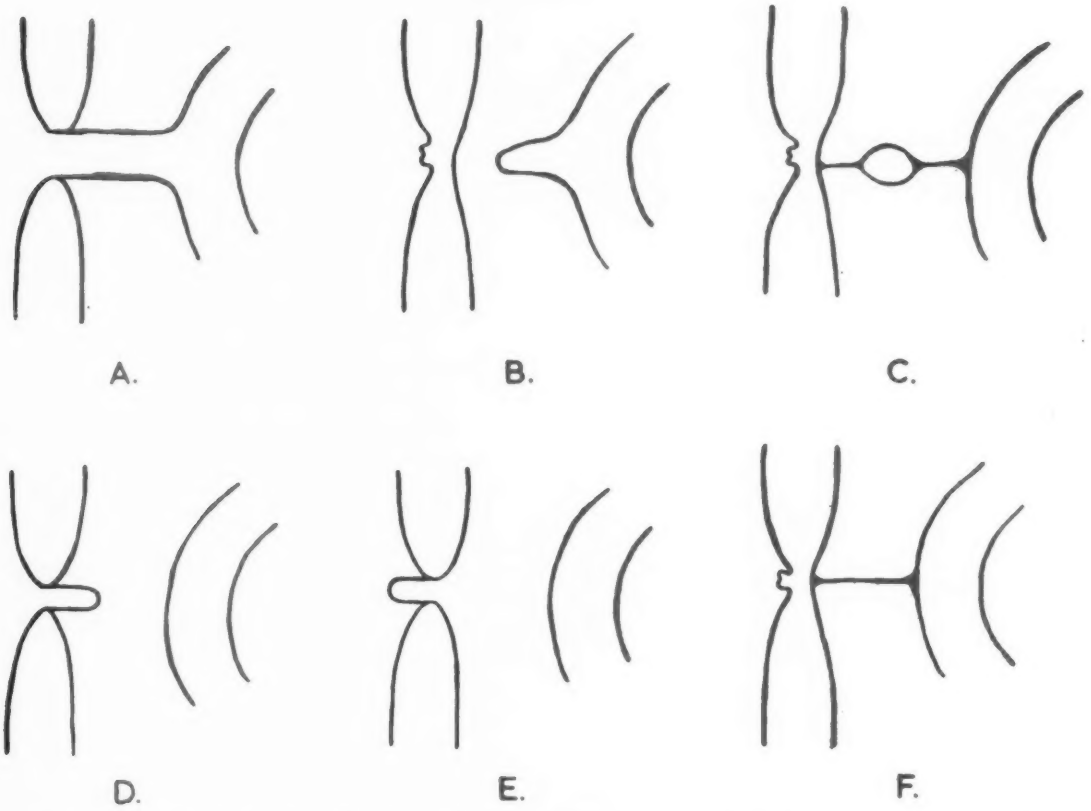

FIG. 1.—A. Vitelline fistula; B. vitelline diverticulum; C. vitelline cyst; D. vitelline sinus; E. prolapsed vitelline sinus; F. vitelline cord.

TABLE 1

PRESENT AND REVISED NOMENCLATURE

Group	Present Nomenclature	Revised Nomenclature
Duplication	Duplication Ileum duplex Enterogenous cyst, etc.	Duplication: Tubular Spherical
Vitelline remnants	1. Patent vitello-intestinal duct Umbilical fistula 2. Enteroteratoma Umbilical polyp Etc. 3. Enterocystoma 4. Meckel's diverticulum 5. Omphalo-mesenteric cord	1. Vitelline fistula 2. Vitelline sinus 3. Vitelline cyst 4. Vitelline diverticulum 5. Vitelline cord
Dorsal enteric remnants	1. Accessory neurenteric canal 2. 3. Mediastinal entero-cystoma Gastric thoracic cyst Archenteric cyst Etc. 4. Giant diverticulum Macrodiverticulum Congenital diverticulum	1. Congenital dorsal enteric fistula 2. Congenital dorsal enteric sinus 3. Congenital dorsal enteric cyst (*a*) Prevertebral (*b*) Postvertebral (*c*) Intraspinal 4. Congenital dorsal enteric diverticulum

part of normal human development, and, since it traverses a cavity, its obliteration is an isolated process. The occurrence of a dorsal enteric fistula is abnormal, hence less common, and, since it traverses spine to reach the dorsal surface, not only has the fistula to be obliterated but the vertebral and neural defects have to be repaired. The various enteric, neural, and vertebral defects persisting after birth represent the varying degrees of success attained. Elongation of the gut during foetal life leads to wide separation of the original spinal and enteric regions, hence the association of cervical and thoracic spinal anomalies with caudad enteric lesions.

Analogous with vitello-intestinal remnants one may find (Fig. 2):

(1) Congenital dorsal enteric fistula when the whole tract persists and presents as a fistula passing from gut through spine and cord to open on the midline posteriorly.

(2) Congenital dorsal enteric sinus when only the posterior part persists.

(3) Congenital dorsal enteric cyst when an inter-

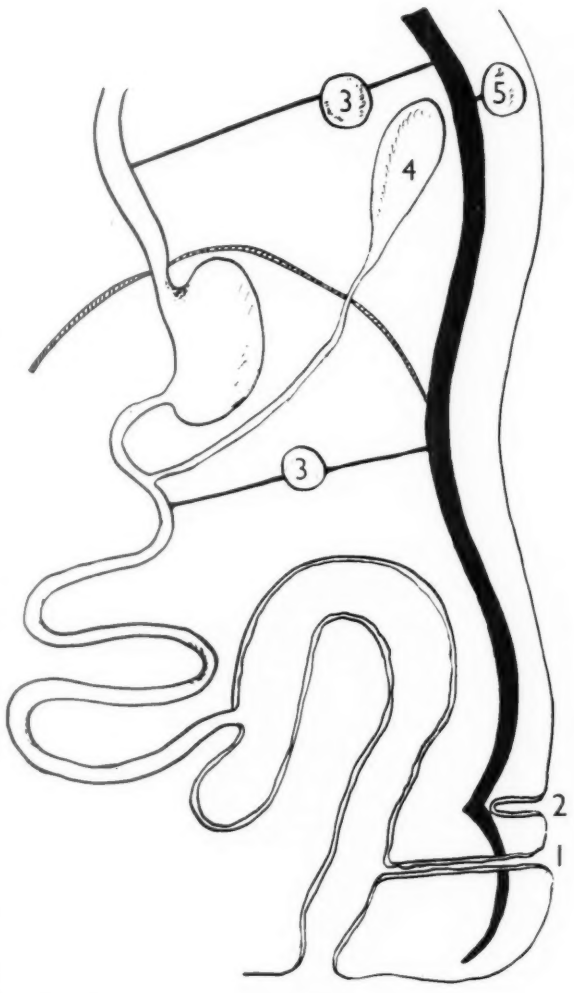

FIG. 2.—1. Dorsal enteric fistula; 2. Dorsal enteric sinus; 3. Dorsal enteric cyst; 4. Dorsal enteric diverticulum; 5. Dorsal enteric cyst.

mediate part persists. The cyst may be pre- or post-vertebral or intraspinal in position, and may have fibrous attachments to gut or spine.

(4) Congenital dorsal enteric diverticulum when only the anterior part persists and connexion with the lumen of the gut is maintained.

There may be varying degrees of concomitant vertebral abnormality with diastematomyelia or diplomyelia. This aspect is discussed more fully in another communication (Bentley and Smith, 1960).

Summary

A classification and nomenclature of accessory enteric formations is proposed which should end the present confusion and facilitate the recognition of the less common types.

I wish to express my gratitude to Mr. W. M. Dennison for advice in the preparation of this paper, to Mrs. Glover for secretarial assistance, and to Mr. Devlin for the illustrations.

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TOTAL COLECTOMY AND ILEO-ANAL ANASTOMOSIS IN THE TREATMENT OF ULCERATIVE COLITIS IN CHILDREN*

BY

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Modern trends in the treatment of ulcerative colitis are pointing towards earlier and more radical surgery. Ileostomy is no longer found adequate, simultaneous ileostomy and subtotal or total colectomy being the method preferred by most experienced surgeons.

In childhood the disease is relatively rare; in a large series only about one-tenth of all the cases occurred in children (Bargen and Kennedy, 1955). It is, however, apt to take a more serious course. The mortality after medical treatment is high. In a large Swedish series it was 12% (Lagercrantz, 1955). According to the same series, the chronic, intermittent is the most common type, comprising 79% of all cases. The disease results in gross delay of growth and maturity and because of long periods of hospitalization the children are unable to follow their normal school education. Cancer is a rare complication in childhood, but cases starting in childhood and persisting 10-20 years are more liable to malignancy than those starting in adulthood. According to Rosenquist, Öhrling, Lagercrantz and Edling (1959), 17 of 26 cases of cancer developed in ulcerative colitis were taken ill with their primary disease before the age of 15, and cancer may appear even after years of apparent cure. Consequently it must be of current interest to discuss the advisability of early and radical surgical treatment of ulcerative colitis in childhood also.

At the University Clinic of Paediatrics in Copenhagen we have during the last two years performed four colectomies for ulcerative colitis in children, two cases being of the chronic intermittent type and two of the acute, fulminating type. Our first case was interesting in more than one sense.

The patient, a 13-year-old girl, developed ulcerative colitis at the age of 2 years. She had been hospitalized several times during infancy, and was treated medically according to the current methods until the age of 11 when an ileostomy was performed. This operation had a very good effect upon her general condition although the inflammatory changes persisted. One and a half years later a subtotal colectomy was performed. The colon was grossly inflamed with large ulcerations and pseudopolyposis and in two different areas in the transverse colon cancer had developed (Fig. 1). The

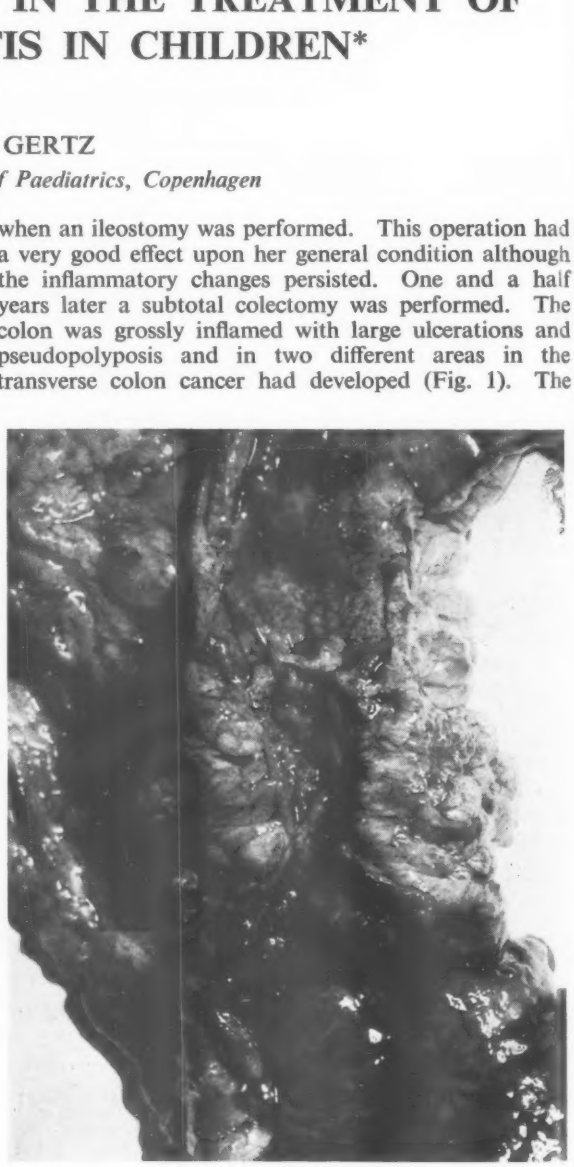

FIG. 1.

rectum was not removed. The operation was thought to be radical and the post-operative course was smooth.

Two months afterwards an ileo-rectal end-to-side anastomosis was done. On this occasion no signs of recurrence of the cancer were found, but three months

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

later she was readmitted acutely ill with symptoms of ileus. At laparotomy it was found that she had a diffuse peritoneal carcinosis. Of course nothing could be done and the child succumbed to her disease in a month. At autopsy it was found that a severe ulcerative proctitis had recurred.

From this case we learned firstly that cancer may very well develop in spite of an ileostomy, showing the importance of a total or subtotal colectomy, once surgical treatment has been decided upon. Secondly we learned that ileo-rectal anastomosis is not the ideal procedure since it may be followed by recurrence of a haemorrhagic proctitis.

Ileo-rectal anastomosis has been advocated for selected cases by several authors (Corbett, 1958; and Aylett,1957, in England) and has also been used in children (Ehrenpreis, 1959). We feel, however, that owing to the risk of relapse of ulcerative proctitis in the remaining part of the rectum and also to the risk of cancer, total colectomy must be the preferred procedure. Since a permanent ileostomy, even with modern equipment, is very incapacitating, especially in a child or a young person, we decided to attempt an ileo-anal anastomosis.

Up till now we have done this operation in two cases. They have both been operated on in two stages, the first stage being ileostomy and subtotal colectomy. Six months later we anastomosed the ileum to the anus and removed the rectum using the pull-through technique described by Swenson (1958) for Hirschsprung's disease. We have found it important to postpone the second stage at least six months. In the intervening period the general health can be re-established and the blood chemistry, which may be difficult to keep within normal ranges during the first period after ileostomy, can be regulated. Also in the span of six months the stools will become semi-solid, owing to an increasing absorption of liquid from the terminal ileum, and are thus less irritating.

From a technical point of view the second stage has been easy, the only difficulty being the isolation of the rectum down to the anus. Because of inflammation it was in both cases very adherent to the surrounding structures. The removed rectum was in both cases grossly inflamed except for the most distal part.

Our first patient thus treated was a 13-year-old girl. Her illness started at the age of 5 years and was of the chronic, intermittent type. The final operation, an ileo-anal anastomosis, was performed a year ago. She is now in excellent health. She has four to five bowel movements during the day, the stools being semi-solid and not irritating, and she is completely continent and undisturbed during her sleep. She now attends school without absence.

Our second case was a 7-year-old boy with an acute fulminating ulcerative colitis. The ileo-anal anastomosis was performed a couple of months ago. With the exception of some incontinence his convalescence was uneventful. On discharge, which took place only recently, he was in excellent health with a promising weight curve.

A third case, a 13-year-old boy, also suffered from the acute fulminating type and had a colectomy six months ago (Fig. 2). He still has his ileostomy and is in very good condition. It is our intention to perform an ileo-anal anastomosis this autumn.

FIG. 2.

Summary

In children ulcerative colitis is apt to take a rather fulminant course. Medical treatment is tedious and takes a very long time. In our experience children will stand a radical colectomy and ileostomy very well and will develop in a natural way afterwards. It has, however, been our aim to avoid an incapacitating permanent ileostomy. An ileo-anal anastomosis, using the same technique as in Swenson's pull-through operation for Hirschsprung's disease, has up till now been used in two cases and seems to be a promising solution.

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SURGICAL ASPECTS OF PATENT DUCTUS ARTERIOSUS*

A REVIEW OF 228 CASES

BY

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Three years ago Hay and Ward (1956) reviewed the results of surgery for 108 cases of patent ductus arteriosus treated at the Royal Liverpool Children's Hospital. The object of this communication is to review the present position at the same hospital from the purely surgical point of view. A further 120 cases have received surgical treatment up to December 31, 1958, making a total of 228 cases available for review, with a minimum follow-up period of five months.

Surgery of patent ductus arteriosus comes of age this year as on August 26, 1938, Gross performed the first ligature operation (Gross and Hubbard, 1939). But the literature on the surgery of patent ductus arteriosus is not very large, considering that the abnormality is such a common one. In fact the contributions of Gross and Hubbard (1939) and Gross (1952) mark the only real major landmarks in the surgery of the condition, reporting the technique of simple ligation and of division respectively. In this second paper Gross reports the extraordinary number of 482 divisions of the patent ductus with 10 deaths. Shapiro and Johnson (1947), reporting 626 operations for patent ductus performed by 48 surgeons, record a mortality of 4·9% and a recanalization figure of 8·7%. They report 172 divisions of their own with no fatality and no recanalization. They state categorically that the operation of ligation is obsolete and should only be done when division is impracticable. Yet even now many surgeons, the present writer among them, have felt a natural hesitancy in substituting the technically more difficult procedure of division for the rather easy one of ligation.

Since Hay and Ward's first report, two other large series of operations for patent ductus arteriosus have appeared in the English literature. Nicks and Molloy (1956) describe a series of 155 cases from New Zealand with 138 operations. In all but five cases the surgical method used was double ligation with silk, and there were only three recurrences in the 80 cases which had adequate follow-up details. The overall mortality was 2%. Mozen (1957) reviewed 143 cases operated on in Dr. Claude S. Beck's clinic in Cleveland, Ohio. The overall mortality was 2·14%. The surgical method used for closure was ligation and suture in 53 cases, division in 88 and exploration alone in two. Only one example of recanalization is mentioned as having taken place in the whole series, though follow-up details may be incomplete.

The fact that division may be proved statistically to be safe should not be allowed to obscure the fact that the division of a large blood vessel must carry with it an appreciable risk from accident. Nor can it be said categorically at the present time that a suture line in such a major vessel as the aorta or the left pulmonary artery is free from the risk of development of a weakness at some future date. Nevertheless the review made by Hay and Ward (1956) shows that the results of the simple ligation operations are far from perfect. Although there was only one death in 108 cases (a case in which the ductus was not tied because a reversed shunt was found) there was in fact failure to secure closure of the ductus in 10 cases, while a further four showed evidence of recanalization during a period of observation varying from one to 12 months. In addition, operation was abandoned on one occasion because friability of the ductus led to difficulty in dissection and to haemorrhage, which was controlled only with difficulty. Even if the case with the reversed shunt is excluded, together with two of the early recanalizations which appeared to close spontaneously, we are left with the uncomfortable fact that the object of the surgical procedure was not completely successful in 13 of the 107 'eligible' cases (a failure rate of 12%). Here one must say that there was evidence of reduction of the shunt in all these cases. The 'gross' failure rate for all cases was 14% (16 in 108 cases). In the ensuing discussion this series of cases

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

will be referred to as Series 1, the newly reported group as Series 2.

The Technical Problem

When the causes of failure to close the ductus were considered, it immediately became apparent, as Hay and Ward pointed out, that there was a close relationship between the success of the operation, then performed entirely by the method of double ligature, and the diameter of the ductus. In 53 cases in which the diameter was 7 mm. or less there was not a single recanalization, whereas this process was observed in no fewer than 16 of the 55 cases in which the ductus had a diameter of 8 mm. or more. In fact only eight of the 20 cases in which the diameter was in excess of 10 mm. were permanently closed by ligature (Table 1).

TABLE 1

EFFICIENCY OF CLOSURE RELATED TO SIZE OF DUCTUS

	Diameter of Ductus (mm.)				
	Less than 5	5–7	8–10	More than 10	Total
Series 1	4 (–)	49*(–)	35 (4)	20†(12)	108 (16)
Series 2	3 (–)	66*(1)	39 (2)	12 (2)	120 (5)
Total	7 (–)	115 (1)	74 (6)	32 (14)	228 (21)

Figures in brackets indicate number of failures
* Includes two cases of 'small' ductus, size not recorded
† Includes five cases of 'wide' ductus, size not recorded

While the magnitude of the failure rate with larger ductuses was not at once appreciated by us, it had for a long time been obvious that the very large ductus was not technically suitable for ligation. One reason for this is that the large ductus usually has a large flow through it with a raised pressure in the pulmonary artery. The very large ductus, in which the diameter is greatly in excess of its length, with its sclerotic walls, presents a formidable surgical problem.

This was at first tackled by attempting ligation by linen thread over a small pad of gauze or lint. This often seemed to result in obliteration of the lumen at the time of operation, but in only one instance (a 14 mm. ductus) was the closure permanent. Next the effect was tried of tying ligatures while the blood pressure was temporarily lowered by the ganglion-blocking agent Arfonad. This again seemed usually to provide satisfactory immediate closure, but the end results were equally disappointing.

With this unsatisfactory situation in mind the methods of closing the ductus were reviewed. First of all a point of anatomy was made which is not always appreciated. The ductus in the unborn child is virtually a continuation of the pulmonary artery, and has an oblique entry into the aorta which is in most instances maintained even after the pulmonary circulation has been opened up by the establishment of breathing. When the ductus fails to close and the left to right shunt becomes established, the blood has to take a very sharp turn back into the pulmonary artery from the aorta (Fig. 1a). This no doubt

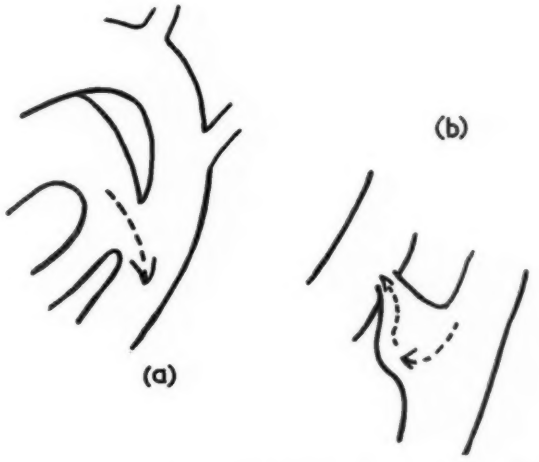

FIG. 1.—Evolution of patent ductus arteriosus (*a*) in foetal life; (*b*) in extra-uterine life.

accounts for the observation frequently made at operation, that the thrill is usually much more obvious in the main trunk of the pulmonary artery than in the left branch. But, in addition, there is a point of impact of the stream on the area of the aortic wall immediately adjacent to the origin of the ductus, but on the distal (caudal) side of the actual orifice. Much as a river erodes its banks on the convexity of a curve, so must this stream of blood, which is often nearly reversed in direction, exert a continual pressure on this area. The common shape of the ductus is conical, with a much wider opening into the aorta than into the pulmonary artery (Fig. 1b). The aorta itself is frequently appreciably wider just below the ductus than above it for the same reason. The ductus has often been described as spindle-shaped or cylindrical, but in the author's experience this is only exceptionally the case. The short, wide, 'high-pressure' ductus may be virtually cylindrical if it can be said to have any length at all, but the average ductus only assumes a spindle shape if traction on it pulls out some of the wall of the pulmonary artery. Firm pressure just in the angle between the aorta and ductus will restore the apparent cylindricity of the

vessel, and indeed a ligature may be tied here without much difficulty. Such a ligature tends, however, to be obliquely placed and is as insecure as if an attempt were made to close a hole in the side of the aorta by ligation (Fig. 2). It is naturally

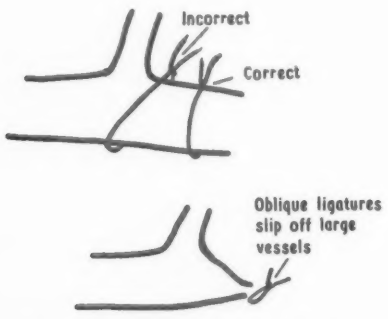

FIG. 2.—Correct and incorrect ligatures.

pushed towards the narrowest part of the ductus and then will not fully occlude the lumen of the vessel. The truly effective position for an occluding ligature is at the narrowest point of the ductus, and perhaps a single ligature properly placed there will suffice to obliterate the vessel. Many surgeons recommend multiple ligatures on the ductus; yet if further ligatures are to be tied after the ductus has been ligated at each end, there is a real danger of causing a rupture of the ductus, with catastrophic haemorrhage as a result.

Blalock (1946) met this difficulty by applying an encircling suture at each end of the ductus, transfixing the ductus in the middle and tying another ligature over it. Such an encircling suture at the aortic end would tend to come under excessive tension and might not be truly effective in maintaining permanent closure. A simpler method, which has been used more recently in our cases, is to ligate the ductus near the aortic end and then to close the lumen by a multiple transfixion suture of 3/0 arterial silk placed at the narrowest portion of the ductus (Fig. 3). A second ligature, which was passed but not tied before applying the stitch, is then tied over the narrowest portion of the ductus, that is, near the pulmonary end.

It is probably important to use correct ligature material but there is some difference of opinion among surgeons as to which is best for the purpose. We had formerly used a rather fine (No. 35 or 40) linen thread but latterly changed to the stronger No. 25 thread and feel that this is more satisfactory. Linen thread is stronger than silk and holds a knot very securely: it seems likely that a very thick strong ligature, e.g. the 'umbilical tape' of American authors, will give a less satisfactory closure than a medium sized thread.

Finally, division of the ductus has been undertaken in cases when it is large or unusually thick-walled. The method we favour is one learned from Professo

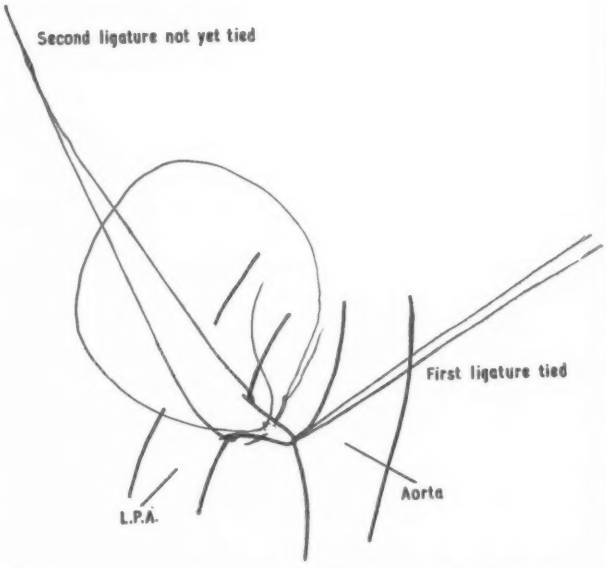

FIG. 3.—Ligatures and transfixion suture of patent ductus arteriosus.

A. G. Brom of Leiden, in which Potts' aortic clamps are applied from the lateral aspect of the ductus, which gives more room than if they are placed in the long axis of the descending aorta. The vessel may be progressively divided and sutured, usually without undue difficulty. Clamps similar to Potts' aortic clamps but bent at a right-angle (designed by Miss I. Forshall for neonatal oesophageal surgery)* are very satisfactory when applied to a patent ductus and provide more room for manipulation. The first row of interrupted sutures is covered by a continuous suture on each vessel. It is important if the ductus is wide and short to dissect out and mobilize the aorta above and below the ductus as if for resection of a coarctation. If the ductus is very large it is wise also to open the pericardium in front of the vagus nerve in order to have the left pulmonary artery under direct observation and control in the event of difficulty.

Review of Surgical Material

In Hay and Ward's original series (1956) there were 108 cases and a further 120 are reported here, making a total of 228 cases of patent ductus arteriosus dealt with surgically. There were two deaths in the

* Manufactured by Messrs. Charles F. Thackeray & Sons, Ltd., of Leeds.

whole series, one being the case reported in the first series, where a reversed shunt was found to be present at operation (left to right shunt at previous catheterization) and the ductus was not tied. The second death occurred in the second series and was in a 13-year-old boy with a ductus 14 mm. in diameter and with considerable pulmonary hypertension. Division was successfully accomplished but convalescence was marked by a persistent systemic hypertension, the significance of which was not properly appreciated. He was readmitted 12 weeks after operation and died of uncontrollable haemorrhage during attempted surgical cure of an aneurysm at the site of resection. Autopsy showed that there was a coarctation of the aorta which had been outwardly marked only by a slight curvature of the vessel. This had been noted at the original operation but had not been thought to indicate any significant narrowing of the lumen. If the true situation had been understood it might have been possible to resect the coarctation at the original operation, but because the collateral circulation was undeveloped this may well have proved hazardous.

Other deaths have occurred after ligation of a patent ductus but only when the ductus was one of a group of complicated cardiac abnormalities. Only cases in which the patent ductus was the dominant lesion are included in the present series.

Table 1 gives the composition of the two series grouped according to the size of the ductus and also indicates the failure rate in each group. All cases in which the diameter of the ductus was 7 mm. or less were treated by ligation with or without transfixion suture. In our second series of 120 cases there were 69 in this group and the only failure was in an infant with a ductus 6·5 mm. in diameter and with exceptionally thin walls. Recanalization followed this operation and it may be that the sutures slowly cut through the thin vessel walls. Of 51 cases with a diameter of 8 mm. or more there were four recanalizations and three further cases have murmurs which are suggestive, though not diagnostic, of recanalization. The cases with definite recanalization had ductuses with original diameters of 9 mm. (two cases), 14 mm. and 15 mm.; those in which recanalization was suspected had diameters of 8 mm., 9 mm. and 11 mm. Although recanalization represents failure to achieve the aim of the operation, in all cases the condition of the patient had improved and the shunt appeared to be much smaller than before operation.

Method of Closure

In the first series the only method of closure employed was double ligature. Table 2 shows the methods of closure adopted in Series 2. Simple ligature was employed 70 times with five certain and three doubtful recanalizations, ligature and transfixion suture in 40 cases with no recanalization, and division in 10 cases with no recanalization.

TABLE 2
OPERATIVE PROCEDURES FOR PATENT DUCTUS ARTERIOSUS, 1954-58 (SERIES 2)

Operation	Cases (No.)	Recanalization
Simple ligature	70	5 (+3?)
Ligature and transfixion suture	40	0
Division	10	0
Total	120	5 (+3?)

Taking the series of 228 cases as a whole it is clear that the risk of recanalization after simple ligation is very small indeed if the ductus is 7 mm. in diameter or less. There was only one example in 122 cases of this size treated in this way.

One hundred and six cases had a patent ductus 8 mm. in diameter or larger, and the situation with regard to these is shown in Table 3. It will be seen that 18 of these cases were not permanently closed after operation, a failure rate of 16%. All these failures were in cases treated by simple ligation. As before mentioned, the failure rate was especially high when the ductus was more than 10 mm. in diameter. Fewer than one in three of these cases (eight out of 22) could be closed by ligation, and recanalization followed in four others. Thus, simple ligation gave permanent closure in less than half of this group of 22 children with a large ductus treated by this method. In the intermediate size of 8 to 10 mm. six out of 66 cases (9%) were not permanently closed.

TABLE 3
PATENT DUCTUS ARTERIOSUS OVER 8 MM. IN DIAMETER (COMBINED SERIES)

Operation	Size of Ductus (mm.)	Cases (no.)	Failure to Close	Re-canaliza-tion
Simple ligature ..	8–10	62	2	4 (+2?)
	Over 10	22	8	4 (+1?)
Ligature and transfixion suture	8–10	9	—	—
	Over 10	2	—	—
Division	8–10	3	—	—
	Over 10	6	—	—
Operation abandoned	8–10	—	—	—
	Over 10	2	2	—
Total ..		106	12	8

By contrast there were no failures and no recanalizations in 11 cases treated by ligation and

transfixion alone. The numbers are small and may not be really significant but they suggest that this technique may possibly give better results.

Nine cases in this group of large patent ductus were treated by division with a successful outcome in all except the one death from a hidden coarctation recorded above.

In our last 91 cases there have been no certain recanalizations, although the three doubtful examples are to be included among these. Of these 91 cases, 41 were ligated simply, 40 had an additional transfixion suture as described and 10 were divided. For what it is worth the doubtful recanalizations were all in the group of simple ligations.

Conclusion

Simple ligation is a safe and easy method of obliteration of the patent ductus when the diameter is 7 mm. or less. It may be even more secure if a transfixion suture is employed in addition. Above 8 mm. it seems clear that division should be the method of choice. Our second series of cases covers a transition period in our surgical policy but the failure rate of 4% (five in 120 cases) compares favourably with the previous figure of 14% (16 in 108 cases). Further reduction of the failure rate is probably dependent on more extensive use of division of the medium sized ductus. The overall mortality was 0·9% (two deaths in 228 cases).

Summary

Two hundred and twenty-eight cases of patent ductus arteriosus treated surgically are reviewed.

In 122 cases the ductus was 7 mm. or less in diameter; all were ligated with or without transfixion suture and there was only one recanalization.

In 106 cases the ductus was 8 mm. or more in diameter. In 18 (16%) cases closure was either not complete or not permanent. All failures occurred after simple ligation.

Simple ligation, preferably with a multiple transfixion suture, gives satisfactory closure of the small patent ductus (7 mm. or less in diameter).

Where the patent ductus is 8 mm. or more in diameter permanent closure can only be ensured by dividing it.

Most of the cases reported in this paper were under the care of Professor John D. Hay, and it is a great pleasure to record my indebtedness to him for his stimulating help, both in the clinical work involved and in the preparation of this report.

My thanks are also due to Dr. H. Gordon Farquhar, who referred many cases for operation; to Dr. Olive Scott and Dr. Gerard Gearty for their invaluable part in the diagnosis, post-operative care and follow-up of the patients; and to Miss Barbara Duckworth, medical artist, of the Department of Surgery, University of Liverpool, who made the drawings.

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VESICO-INTESTINAL FISSURE*

BY

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The great advances in paediatric surgery during the last two decades have brought about a change of attitude towards infants and children suffering from severe congenital malformations. A large number of these anomalies can now be satisfactorily treated and following the operation the child will be normal or nearly normal.

There are, however, still malformations or malformation complexes which are thought to be either untreatable or unjustifiable to treat as the child will remain more or less handicapped even after the most successful operation. These are mainly malformations of the central nervous or genito-urinary systems. It is my belief that in the next decade paediatric surgery will have to come to grips with these problems. We shall have to re-examine the contention that these children will never make useful members of society and are better left to die. We shall have to realize that with modern methods in physical education and rehabilitation much more can be done. This has been shown, for instance, in the management of spastic children. We shall also have to admit that with antibiotics and modern nursing care many of these children do not die or only die after a long time, a prolonged agony for them and their families alike.

I am prompted to this introduction because the condition which I am about to discuss is either not mentioned at all in the textbooks of paediatric surgery or urology or, if briefly described, it is dismissed as untreatable. There have been a few references in the literature to attempts at operation but as far as I can ascertain they have all ended in failure (Swan and Christensen, 1953). This prompts me to describe our experience in the treatment of this condition.

Definition and Description

The name vesico-intestinal fissure was introduced by Schwalbe in 1909, but the malformation has been given a number of different names, such as ectopia vesicae with Meckel's diverticulum opening on the exposed bladder surface, extrophy of the bladder and colon, ectopic cloaca, etc. (Keith, 1908; Campbell, 1951; Williams, 1957).

In this condition there is an ectopia vesicae, which is often split into two lateral fields by an intervening zone of ectopic intestinal mucosa. If two kidneys are present, each ureter opens into the corresponding bladder field, but frequently one kidney is absent and malformation and displacement of the kidney is common. The intestinal mucosa belongs to the ectopic caecum. The opening of the appendix is often visible and the lower ileum tends to prolapse through the ileo-caecal valve forming a striking, bright red, sausage-shaped tumour. The colon is rudimentary and usually ends in front of the sacrum; the anus and rectum are always absent (Fig. 1). Duplication of some part of the lower intestine, such as the appendix or colon, is not infrequent. There is always an exomphalos situated above the ectopic intestinal field and a small myelo-meningocoele or meningocoele is frequently present; in one of our cases it only developed two months after birth.

The penis or clitoris is usually, although not invariably, split and the two halves widely separated. In one of our cases we were able to demonstrate, with the aid of serial sections of the autopsy specimen, that there were two complete penes each with a completely formed urethra, corpora cavernosa and spongiosa and prostate gland (Fig. 2).

Incidence

We saw our first case of vesico-intestinal fissure in 1953 and then considered it to be a great rarity. There are, however, a very large number of reports of this malformation in the literature since Meckel described the first case in 1812. In the last six years we have seen four cases as compared to 22 cases of ectopia vesicae and it appears quite possible that the condition is more common than is usually realized as many of the apparently hopeless children may not reach surgical centres.

* A paper read at a meeting of the British Paediatric Association held in Liverpool in June, 1959.

FIG. 1.—Perineal view. The two penes are clearly shown. There is no anus.

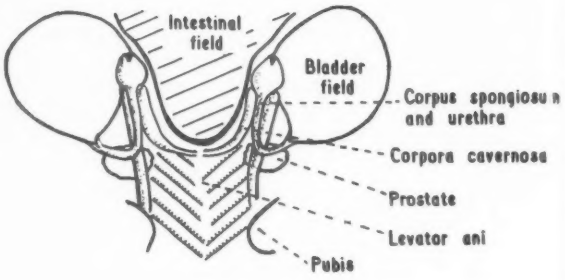

FIG. 2.—Schematic drawing of dissection of case shown in Fig. 1.

Embryology

Vesico-intestinal fissure has been of great interest to embryologists because the malformation throws some light on the embryology of the cloaca, the lower abdominal wall and the causation of ectopia vesicae. In this context it is impossible to give a detailed description of the various opposing views regarding the embryological aetiology of the condition which we discussed in a previous article (Hall, McCandless and Rickham, 1953). It suffices to state that the hypothesis recently brought forward by Patten and Barry (1952), and especially their resurrection of Keibel's (1896) view that the genital tubercles are primarily paired structures, has done much to explain most important features of this intriguing malformation (Fig. 3).

In the very early embryo the paired genital tubercles develop near the cephalic border of the cloacal membrane towards the end of the second week of intra-uterine life. They migrate towards each other and by the fifth week they fuse in the midline, reinforcing the cephalic border of the cloacal membrane (Fig. 3 (A_1, A_2, A_3)). It is thought that in ectopia vesicae the genital tubercles develop somewhat caudally to their normal position, approximately opposite the point where the uro-rectal fold comes to the surface. If they now fuse in the midline the genital orifice will be cephalic and the anal orifice caudal to them (Fig. 3 (B_1, B_2, B_3)). We developed this theory a stage further and assumed that if the paired genital tubercles develop still more caudally than with ectopia vesicae, they can now only fuse in the midline caudal to the cloacal membrane. There would then be a deficiency of secondary mesoderm over the whole of the hypogastric area and the extensive cloacal membrane would break down. If the membrane ruptured immediately after the formation of the tailfold, it would expose the dorsal and lateral walls of the hindgut. As Johnston (1913) has pointed out, the whole of the gut distal to Meckel's diverticulum is derived from the hindgut. It will be seen that the above hypothesis explains the intestinal ectrophy and the frequent association with widely separated split penis or clitoris (Fig. 3 (C_1, C_2, C_3)).

Treatment

Some details of the treatment of our four cases may be of interest because these show all the pitfalls in the treating of this condition and also how we were able to learn from our mistakes.

Case 1. The first case, a boy weighing 5 lb., was admitted moribund and any active treatment was out of the question. He died on the third day. A careful post-mortem dissection enabled us to form a detailed picture of the pathological anatomy of the condition.

Case 2. One year later we saw a second almost identical case when a few hours old. This infant was grossly premature, weighing 3½ lb. At operation the extrophied intestinal field was excised and on entering the abdomen it was found that the whole of the distal colon was duplicated (Fig. 4). This too was excised and the lower end of the ileum was pulled through to the perineum (Fig. 5). The two ectopic bladder fields were then united in the midline, the small exomphalos was repaired and the abdomen closed (Fig. 6). The infant stood the operation well, but it soon became apparent that the remaining length of the intestine was insufficient for adequate food absorption. In spite of numerous blood transfusions, plasma, protein hydrolysate and

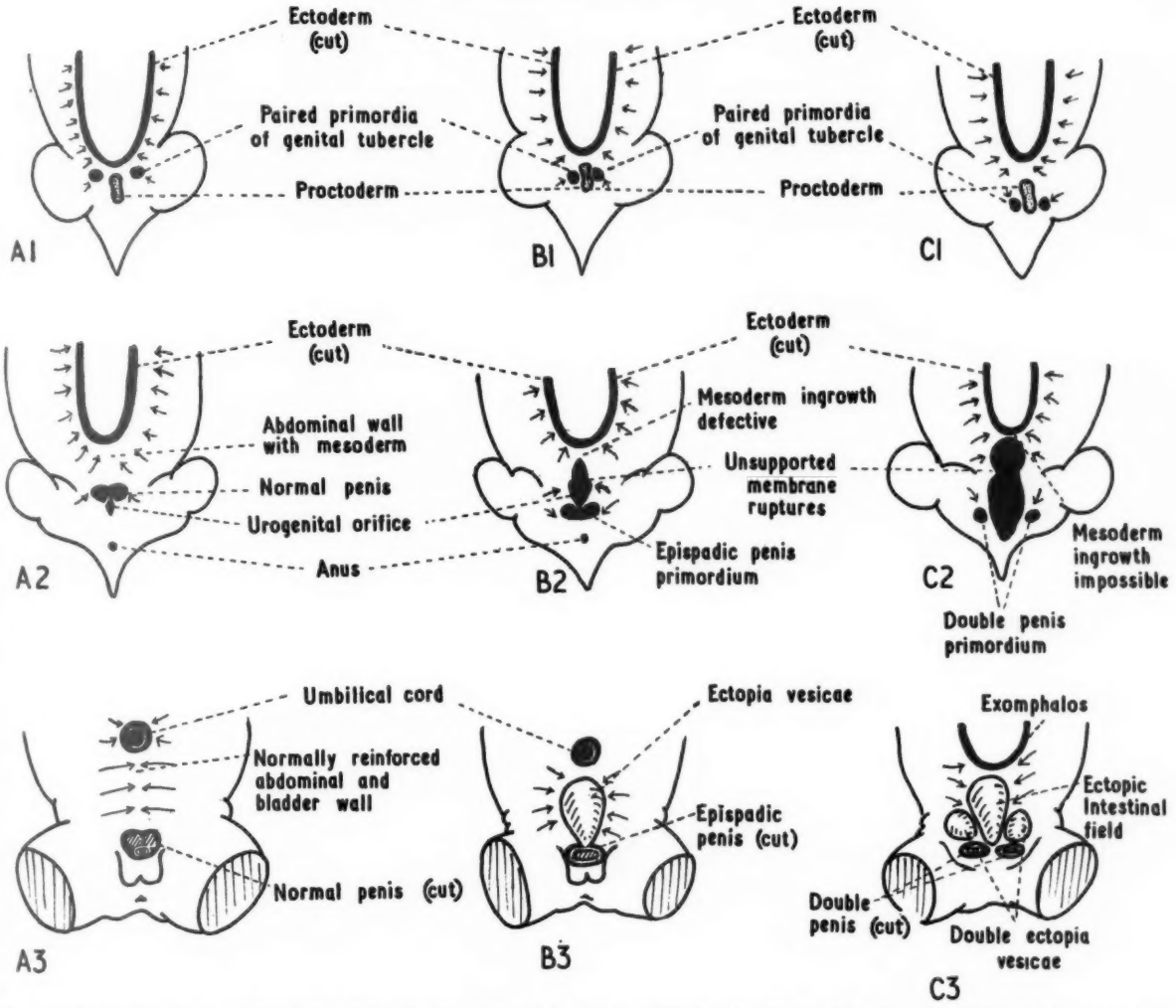

FIG. 3.—Diagrammatic representation of the development of the infra-umbilical abdominal wall in the normal foetus (A), and ectopia vesicae (B). The development of vesico-intestinal fissure can be explained on the same basis (C).

sugar infusions, feeding by intragastric drip of high calorie, high protein concentrates, etc., the infant did not gain weight, continuously passed numerous fluid undigested stools and finally died two months after operation. Since then an identical case, that of Koop (1957), has come to our notice. This child also failed to thrive because of lack of absorption of sufficient nutriment. As these infants were only deprived of their colon and lowest ileum it is somewhat difficult to explain why they did not absorb sufficient food unless their gross prematurity had something to do with this deficiency.

Case 3. The third infant with vesico-intestinal fissure, another premature boy weighing 4½ lb., was admitted six months later (Fig. 7). Bearing in mind our unfortunate previous experience, we carefully preserved the ectopic intestinal field with its blood supply and closed the everted caecum and ascending colon. The distal colon, ending blindly in front of the sacral promontory, was freed and drawn down to the perineum. The two bladder fields were then closed in the midline as before. The exomphalos in this case was, however, a very large one and having already taken up most of the slack of the abdominal wall by suturing the bladder fields together, it now became absolutely impossible to cover with skin the abdominal defect produced by excision of the exomphalos. After several unsuccessful attempts at closure had been made, a piece of sterile nylon sheath was sutured to the mobilized abdominal skin across the defect. To our great surprise the child stood the operation quite well and when the nylon sheath finally separated two weeks after operation, there was granulation tissue underneath it, retaining the intestine inside the abdominal cavity (Fig. 8). Unlike Case 2, this infant thrived, the number of stools was not too excessive and he gained weight satisfactorily. The area of granulation tissue was covered by split skin grafts, and when 3 months old the child had doubled his birth weight.

FIG. 4

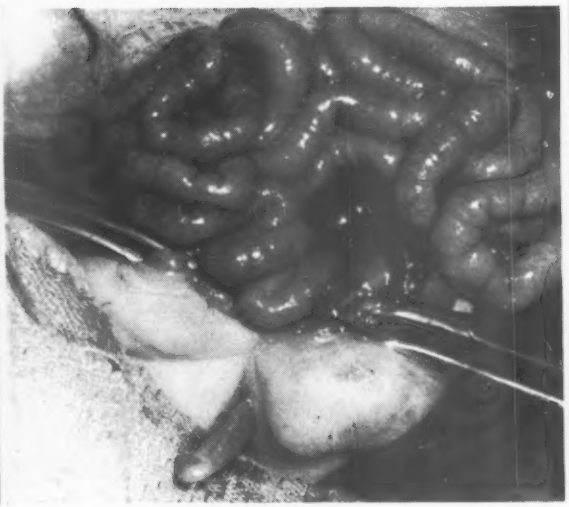

FIG. 5

FIG. 6

FIG. 4.—Excised specimen from Case 2. The duplicated ascending colon, hepatic flexure and rudimentary double transverse colon are shown.

FIG. 5.—Case 2. The terminal ileum has been pulled through a hole made in the perineum.

FIG. 6.—Case 2. At end of operation.

FIG. 7.—Case 3. Note large exomphalos.

FIG. 8.—Case 3. After separation of nylon sheath.

FIG. 9.—Case 4.

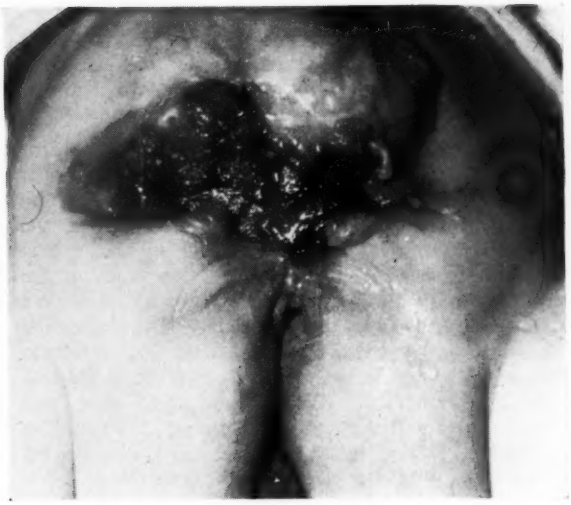

FIG. 10. Case 4, aged 1 year. Note incisional hernia.

FIG. 11.—Case 4, aged 20 months, wearing urinary bag.

He then developed acute mechanical intestinal obstruction and, as conservative treatment was of no avail, his abdomen was opened. As was to be expected, the whole of the small intestine was glued together and closely adherent to the anterior abdominal wall. Only with the greatest difficulties was it possible to relieve the obstruction by dividing numerous adhesions. Although the child recovered from the operation, he had two further attacks of acute intestinal obstruction during the next three weeks, each of them necessitating a laparotomy. He finally died following the third laparotomy.

Case 4. We were somewhat disheartened by this experience and when a fourth case presented 18 months ago we devised a new plan of attack. Instead of opening the abdomen by incising the amnion covering the exomphalos, we now decided not to touch the exomphalos at all, but to enter the abdomen through the opening made by dissection of the intestinal field. We then wanted to proceed as in Case 3, repairing the caecum and pulling the terminal colon down to the perineum, and to close the abdomen by uniting the two ectopic bladder fields. If we found that there was sufficient abdominal wall and skin we would repair the exomphalos; if not, we would treat the exomphalos conservatively, employing Grob's (1957) method.

This child, a boy weighing 5½ lb., born on August 17, 1957, had a medium-sized exomphalos, a split penis and a small sacral myelo-meningocoele (Fig. 9). His legs moved well, both testicles were undescended. At laparotomy on August 18, he presented a picture identical with that of Case 3 with the exception that he had only one kidney, which was situated in the pelvis and had a very short ureter running to the left half of the ectopic bladder. After the bladder fields had been united it was found that there was enough slack in the abdominal wall to allow a complete repair of the exomphalos. The child stood the operation well. The post-operative period was complicated by an attack of mechanical obstruction when the child was 2½ months old. At laparotomy several adhesions had to be divided. The child made an uninterrupted recovery, gained weight slowly but steadily and started to stand up when 14 months old. He had a large incisional hernia (Fig. 10). There was no faecal continence, his perineal colostomy acting twice a day.

On February 20, 1959, it was decided to cut the left ureter off the ectopic bladder and, if possible, to perform a cutaneous ureterostomy in the left iliac fossa. At operation it was found that the length of the ureter was only about 1½ in. An end-to-end anastomosis between the ureter and a segment of isolated left ileum was therefore performed. In order to do this and to use as short an isoperistaltic piece of ileum as possible, it was necessary to rotate the ileal segment and mesentery through 180°, and to bring the loop out in the left iliac fossa. The dissection was made rather difficult by the numerous intra-peritoneal adhesions, but it was possible to rotate the loop without interference to its blood supply and to bring a 3½-in. long segment of ileum out in the left iliac fossa. Although the kidney is now draining urine practically straight upwards, there has been no stasis, and no hydronephrosis has developed. There is hardly any residual urine in the isolated ileal loop, possibly because of the vigorous peristalsis of the segment of intestine.

On April 23, 1959, the two ectopic bladder fields were excised and, after mobilization of the skin, it was possible to suture the wound under some tension. Most of the wound healed by first intention, but a small area in the centre sloughed. At the same time the two corpora cavernosa were divided from the widely separated pubic bones and the two penile halves were without difficulty brought together in the midline. No attempt was made to unite these two halves, but the posterior urethra and a small part of the vesical trigone were repaired.

The boy is now 22 months old and very well. He walks well, talks and appears of normal intelligence. He wears the infant's ileostomy urinary bag previously described (Rickham, 1956, 1958), and can be kept dry for two days at a stretch (Fig. 11). He is incontinent of faeces, but, in our experience, faecal incontinence is not a very great problem when the child gets older, and with the aid of a suitable diet, enemata and training it should be possible to keep him clean. He has intelligent parents and, with luck, his progress should be satisfactory.

In conclusion it should be said that vesico-intestinal fissure, the most severe malformation of the lower urinary tract, is perhaps not as rare as we previously supposed. After trial and error and committing (in retrospect) several stupid mistakes, we believe that the treatment outlined above may prove successful in the majority of cases and that the end result may well produce a useful member of the community.

Miss Isabella Forshall operated on Case 2 and kindly permitted its inclusion in this paper.

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LE MESURIER'S OPERATION FOR HARE LIP*

BY

A. OBERNIEDERMAYR

From the Children's Hospital of the University of Munich

This is a report on hare lip operations performed by the method of le Mesurier (1949). Since 1955 we have done 238 operations on hare lips in the Children's Hospital in Munich. In 98 cases there were unilateral complete hare lips, in 27 cases bilateral complete hare lips. I shall discuss only the primary plastics and not the corrections which are often necessary, and I shall not mention the problem of cleft palate in spite of its connexions with hare lip.

We began in 1957 to operate on total palatoschisis in two stages. In the first operation at the end of the second year we close the soft palate, and the residual cleft is closed before the child starts to go to school. In the meantime we try to diminish the extent of the residual cleft by using a so-called stimulation plate, a method which is described by Schweckendiek (1955), McNeil (1956), and Derichsweiler (1958), but our experience with the stimulation plate is as yet insufficient to form any judgment.

In total unilateral hare lip we have to span the fissure not only in the frontal but also in the sagittal plane. There is no difficulty in closing the gap in the frontal plane, even if it is a very large one, but it is sometimes difficult to close the gap in the sagittal plane. As the two edges of the cleft are in different planes there results an oblique position of the nostril and the columella and a flattening of the wing of the nose at the side of the gap.

There are two problems in hare lip operations, the lip and the nostril. I think we should try at the first operation to undertake the corrections as far as possible, but the plastics of the nostril must not complicate and prolong the operation too long. I therefore postpone the plastics of the tip of the nose and the columella until later, if such correction is necessary at all. It is known that the likelihood of spontaneous correction is much greater in early childhood than later on.

Fig. 1 shows the original method of le Mesurier. At the outermost left side of the picture the final point of the medial incision and the centre of the upper lip do not coincide, but lie a few millimetres nearer to the cleft. The cause for this asymmetry following le Mesurier's operation is the difference in height of the lip on the normal side and the abnormal side. This causes a slight displacement of Cupid's bow towards the side of the cleft except in those rare cases where Cupid's bow is situated on the medial side of the gap.

Fig. 2 shows the incisions in total hare lip. The plastics of the base of the nose we do by the method of Axhausen (1936), using the mobilized flaps of the mucous membrane. We make a transverse incision at the base of the inferior nasal concha to put the lateral part of the cleft forward in the sagittal plane (Fig. 3). The starting points of the incisions we place a little in front of the nostril to have as much material as possible for the base of the nose. To ensure that the vertex of Cupid's bow is in the middle of the lip, the foot point of the medial incision is placed in the calculated middle of the demarcation line of the red border, even if the length of this medial incision is longer than normal, i.e. more than 8 mm. If a good cosmetic result is risked by this procedure we can do a longitudinal correction by excision of a triangle. On the lateral part of the cleft the length of the incision is 8 mm. It is very important that the incisions which form the later flap are exactly half as long as this longitudinal incision and exactly as long as the cross section on the longitudinal medial incision. The angle between the longitudinal and transverse incisions should be 90°. If a longitudinal correction on the lateral side of the cleft is necessary, this can be done by taking off a wedge at the insertion of the nose wing. With regard to the plastics of the wing of the nose, we do not undertake a dissection of both layers (mucous membrane and skin). If a dissection of the cartilages is necessary for a correction of the tip of the nose, for instance, it is very difficult if there has been any lesion of the cartilage in early childhood. The first correction of the sinking in of the side of the nose we do by a Z-plastic. Figs. 4 and 5 show the result of operation.

* A paper read at a meeting of the British Association of Paediatric Surgeons held in Liverpool in June, 1959.

FIG. 1.—Original in *Chirurgische Operationslehre B. Breitner*, Printed in Austria, Copyright by Urban and Schwarzenberg-Wien. Vol. I, Fig. 4 *d-e*, p. 11.

In operations for total bilateral cheilognathouranoschisis, the greatest problem is the prominence of the premaxilla. Browne (1932) has pointed out that we must put the premaxilla in the alveolar curve and must not try to put the lateral parts of the cleft forward. Matthews (1955) was also of this opinion. We agree with Matthews that the retropositioning of the premaxilla should be done as a single operation, but not in the same session as the plastics of the lip. In many cases the gap between the two alveolar processes is smaller than the premaxilla. Therefore we first have to make an extension of the gap. This is done by means of a plastic plate with a screw (Fig. 6); it is quite easy to put the premaxilla in the alveolar curve after the dilatation (Figs. 7 and 8). Within a very short time the gap is wide enough to start resection of the prevomeric bone, as described by Browne (1932). It is very necessary to prevent the premaxilla from tilting inside; we prefer the teeth to stand out a little. For fixation of the premaxilla we use fragments of bone placed at both sides of the premaxilla in the alveolar curve and fix it with small flaps of mucous membrane (Fig. 9). We use the bone obtained in the resection of the premaxilla, divided into two pieces. We perforate the premaxilla and fix it with a piece of Kirschner wire in the sagittal direction; then we mobilize the mucous membrane of the alveolar process and the premaxilla, put the fragments of bone in small fissures

FIG. 2.

FIG. 3.—From *Chirurgische Operationslehre B. Breitner*, Vol. I. p. 22.

FIG. 4.—Unilateral total hare lip before operation.

FIG. 5.—Unilateral total hare lip (same case as shown in Fig. 4) after operation.

FIG. 6.—Extension of alveolar gap with plastic plate.

FIG. 7.—Gap between two alveolar processes is wide enough; pre-maxilla is reduced.

FIG. 8.—Plaster casts before and after repositioning of premaxilla.

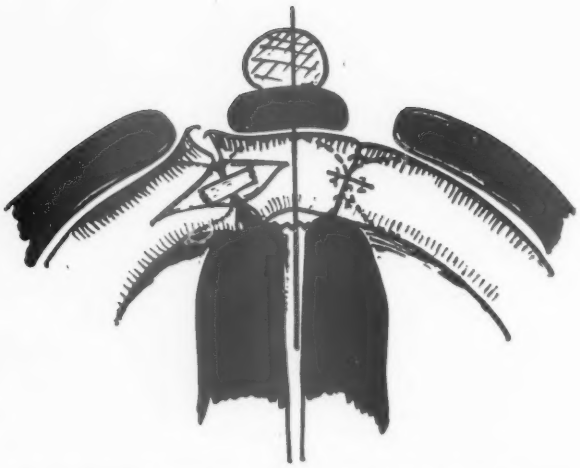

FIG. 9.—Diagram showing effect of resection of prevomeric bone; premaxilla is fixed with a piece of Kirschner wire and with fragments of bone.

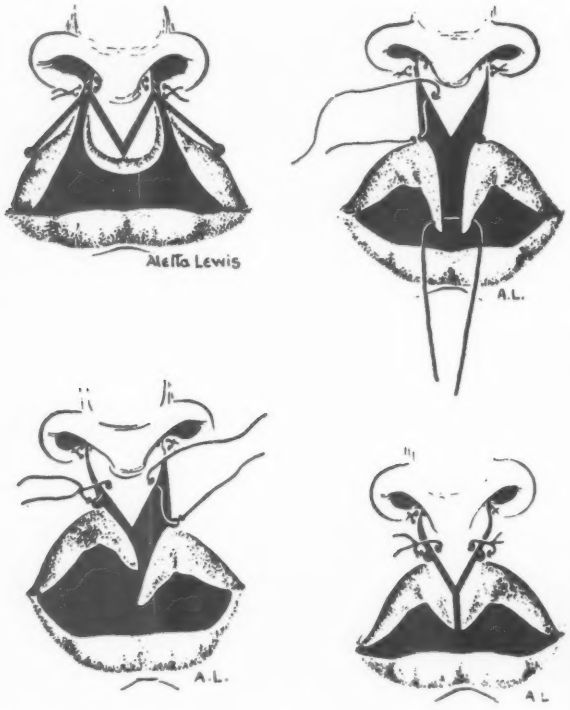

FIG. 10.—Operation for bilateral total hare lip by Denis Browne (*Ann. Royal Coll. Surg. Engiand*, Vol. 5, Sept. 1949).

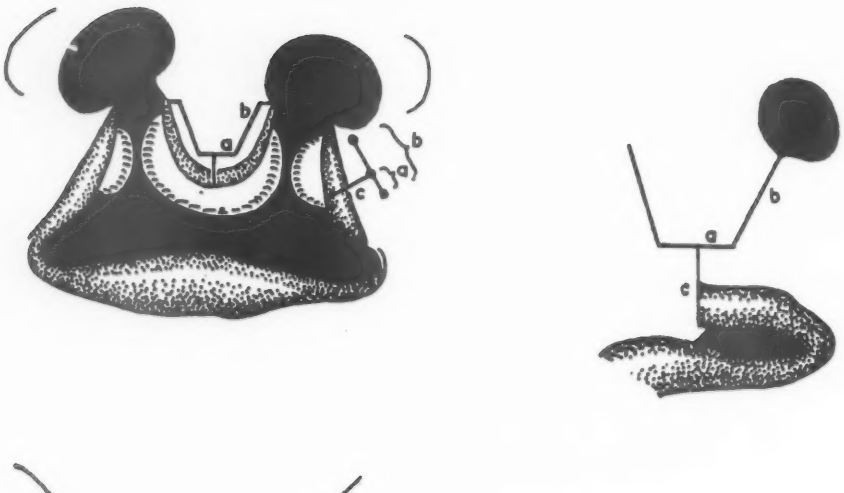

FIG. 11.—Le Mesurier's method at operation for bilateral total hare lip.

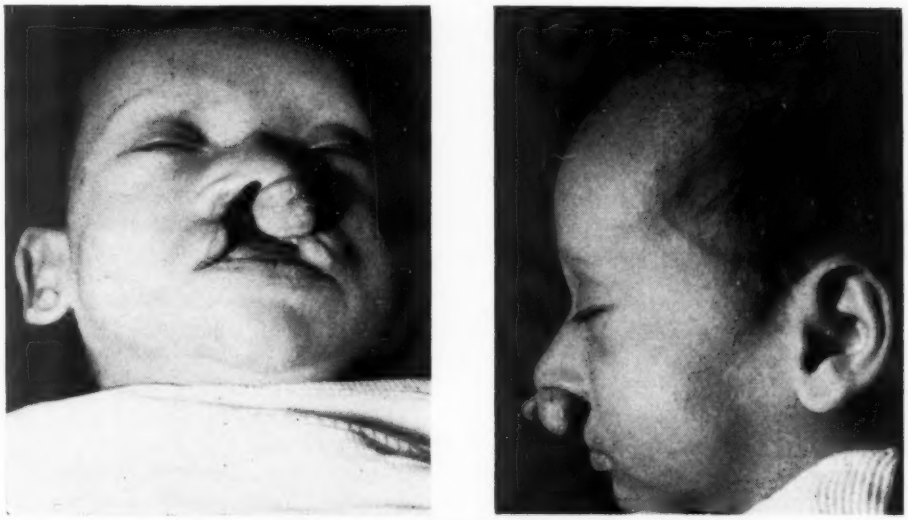

FIG. 12.—Bilateral total hare lip before reposition of premaxilla.

(*a*) (*b*) (*c*)

FIG. 13.—Same case as shown in Fig. 12: (*a*) and (*b*) after reposition; (*c*) after operation.

and make a suture in the mucous membrane. In this way, in the majority of cases it is possible to place the premaxilla in the alveolar curve.

The closure of the hare lip we try to do in one session (Figs. 10 and 11). We use the method of Browne if we have a sufficient amount of material, but if we have only a small middle segment we try separation of the lateral parts of the cleft by the method of le Mesurier.

Figs. 12 and 13 show the result of the operation on a case of bilateral hare lip at the Children's Hospital, Munich.

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CLINICAL MANIFESTATIONS OF PRIMARY HYPEROXALURIA*

BY

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Primary hyperoxaluria is characterized during life by a continuous urinary oxalate excretion level of about 100-400 mg. (expressed as $(COOH)_2.2H_2O$) per 24 hours as opposed to the normal value of less than 45 mg. per 24 hours. Patients with this disease usually present in early childhood with multiple bilateral renal or ureteric calculi which increase rapidly in size and are composed wholly or predominantly of calcium oxalate. Nephrocalcinosis, recurrent attacks of pyelonephritis and hypertensive damage destroy the renal parenchyma and the patients usually die from renal failure later in childhood. Descriptions of cases in which the diagnosis was confirmed chemically during life and which conformed to this clinical picture have been published by Newns and Black (1953), Aponte and Fetter (1954), Archer, Dormer, Scowen and Watts (1957), Godwin, Fowler, Dempsey and Henneman (1958) and Hodgkinson (1958). The characteristic post-mortem findings are widespread destruction of the renal parenchyma by aggregates of calcium oxalate crystals, and similar deposits in the tunicae mediae of the small muscular arteries and arterioles, the myocardium, and the testis (especially the rete testis) in association with the bone trabeculae and at the growing ends of the long bones (Scowen, Stansfeld and Watts, 1959). The term oxalosis (Dunn, 1955) conveniently describes this condition of disseminated extra-renal calcium oxalate deposits.

Mulloy and Knutti (1951), Neiman, Rauber, Pierson and Gentin (1957) and Katzuni and Sandbank (1959) reported cases of infants who died apparently from renal failure at the age of a few months and in whom the findings of calcium oxalate nephrocalcinosis without stones, and of oxalosis also in Katzuni and Sandbank's (1959) case, suggest that they may have been cases of primary hyperoxaluria in which the disease followed an unusually fulminating course. Zollinger and Rosenmund (1952), Lund and Reske-Nielsen (1956) and Öigaard and Söderhjelm (1957) describe the post-mortem findings in cases which may have been examples of primary hyperoxaluria in which stone formation began at an unusually late age. The urinary oxalate excretion was not measured in any of these cases.

The purpose of the present paper is to describe in detail the clinical features of a group of eight cases of primary hyperoxaluria arising in three families, and to comment on some aspects of the natural history of the disease. The results of an investigation of the genetic aspects of the disease, which was based on these and two other families, have been published elsewhere (Scowen, Watts and Hall, 1959) and the families have been numbered serially from four onwards in order to facilitate cross reference to that paper. Three previous families (numbers 1-3) had been investigated and the results recorded (Archer, Dormer, Scowen and Watts, 1958) before the present cases, which provided proof of some of our earlier hypotheses, became available for study.

Case Reports

Family 4. In this family there were 12 children, one dying in infancy of unknown cause. The parents are not related, and they, the unaffected children and other relatives have normal urinary oxalate excretions.

CASE 1. A boy, the second child, was admitted to hospital at the age of $10\frac{1}{2}$ years because of right-sided intermittent abdominal pain, vomiting and haematuria of one day's duration. He had had a similar episode a few months previously, which had resolved without treatment. The present attack subsided spontaneously, but bilateral renal and ureteric calculi were demonstrated radiologically. He remained in hospital for two and a half months and was symptom-free except for one attack of renal colic. During this period his urine, which had initially contained leucocytes, erythrocytes and a trace of albumin, but had remained sterile on culture, became normal. The Sulkowitch test showed a low excretion of calcium, and the amino-acid pattern was normal. The blood urea was at first elevated to 49 mg./100 ml. but the serum sodium, potassium, chloride, CO_2 combining power, protein, calcium, phosphorus and alkaline phosphatase were normal.

Three months later an attack of left-sided renal colic was accompanied by the passage of a calculus, and laboratory tests gave results similar to those obtained previously. An intravenous pyelogram after this episode

* This article includes material given in a paper to the 6th Annual Meeting of the British Association of Paediatric Surgeons in June, 1959, by one of us (E.G.H.).

demonstrated mild bilateral hydronephrosis with slight impairment of dye excretion. Calculi were seen on both sides.

During the next 15 months he had only one mild attack of colic and then passed two small calculi which on analysis were found to consist almost entirely of calcium oxalate. The urine contained a variable slight excess of leucocytes, was usually sterile on culture and the blood urea remained below 40 mg./100 ml.

A high urinary oxalate excretion was demonstrated in March, 1958, and although he had remained in apparent good health for the previous two years, he was readmitted for further study. There were no abnormal clinical findings: marrow aspirate did not show any oxalate deposits, and the eyes were normal on slit-lamp examination. A radiograph of the kidneys showed multiple bilateral stones; there was no abnormality in the appearance of the long bones nor visible calcification in the testes. Laboratory examinations showed a sterile acid urine with excess of leucocytes, a blood urea of 45 mg./100 ml. and urea clearance of 80% with normal figures for blood sodium, potassium, chloride, CO_2 combining power, calcium, phosphate, uric acid and total protein. There was a moderate fall in serum albumin and a rise in globulin, principally gamma globulin. A series of 24-hour urine specimens showed a daily oxalate excretion in the range of 400-490 mg.

At the age of 15½ years, nine months after this admission, he had further left-sided colic, and three months later, although he had passed several calculi, it was necessary to admit him for removal of impacted calculi at the lower end of the left ureter. He had lost some weight, developed marked polyuria and anaemia, but felt fairly well. His blood pressure was 130/100: intravenous pyelography showed gross impairment of renal function and left-sided hydronephrosis, and his blood urea had risen to 100 mg./100 ml. His urine remained sterile but was loaded with leucocytes. At operation three calculi were removed from the distended left ureter. Postoperatively his blood urea rose to 292 mg./100 ml., falling gradually to its present level of 220 mg./100 ml. two months after operation. He has developed a marked anaemia and acidosis, and his daily oxalate excretion, which during the three weeks after operation ranged from 218-320 mg. with urine volumes ranging from 1,800 to 3,300 ml., has now fallen to about 100 mg.*

Calculi were analysed on several occasions and consisted entirely or mainly of calcium oxalate.

CASE 2. A girl, the third child, was investigated at the age of 13½ years because her daily urinary oxalate excretion was 202-214 mg. She had never had any urinary symptoms and was quite well. Physical examination was negative, and radiography did not show any evidence of nephrolithiasis. There were no calcium oxalate crystals in an aspirated sample of bone marrow, and no crystalline deposits could be demonstrated in the eyes by slit-lamp examination. Blood urea, urea clearance, total protein, calcium, phosphorus and uric acid values were normal; the Sulkowitch reaction of the urine was Grade I, and the urinary amino-acids were normal. There was a slight increase in the serum γ, α_2 and β_1 globulins. She has been well for the last year, and oxalate excretion has remained at its initial high level.

CASE 3. A girl, the fourth child, was first admitted to hospital at the age of 7½ years with a two-day history of vomiting, colicky right-sided abdominal pain and anorexia. She had never been ill before. Radiography showed a large right kidney with numerous stones in both kidneys and ureters. The urine was acid with a slight excess of leucocytes and free of pathogenic organisms. The initial blood urea was 145 mg./100 ml. She improved during the next two weeks: further biochemical and radiological examinations did not reveal any evidence of a primary cause for her nephrolithiasis. She passed normal amounts of urine of low specific gravity, and her blood pressure remained within normal limits. Because of a further attack of colic a series of operations on the left kidney and ureter were performed for the removal of stones and she was discharged in fair condition three months after admission, her blood urea having fallen to 25 mg./100 ml. Analysis of the calculi showed the presence of calcium, phosphate and oxalate.

She was readmitted in uraemia a month later, but oliguria persisted in spite of treatment and she died 10 days later. Permission for autopsy was refused. Estimation of urinary oxalate was never performed.

CASE 4. A boy, the eleventh child, was seen at the age of 4½ years because urine examination had shown that he was excreting increased amounts of oxalate. He had not had any urinary symptoms and was perfectly well. Physical examination was negative. Radiography showed small left-sided renal and ureteric calculi. Marrow aspiration and slit-lamp examination did not show any evidence of oxalosis.

Blood urea, urea clearance, total serum protein, calcium, phosphorus and uric acid were normal. The urine gave a Grade I Sulkowitch reaction and the amino-acids were normal. Several oxalate determinations fell within the range 110-130 mg. per day.

Shortly after discharge from hospital he complained of left-sided pain, followed by the passage of a stone consisting entirely of calcium oxalate. He is now 5½ years old and has had no further symptoms, but his oxalate excretion remains high.

CASE 5. A girl, the twelfth child, was first seen at the age of 15 months because she had passed three small urinary calculi. There was no history of previous urinary disturbances. Physical examination was noninformative; the urine was acid and contained a slight excess of leucocytes; blood urea, total protein, sodium, potassium, chloride, CO_2 combining power, calcium, phosphate and alkaline phosphatase were normal. A radiograph of the abdomen showed a calculus in the right renal pelvis.

She was admitted for slit-lamp examination of the eyes and marrow aspiration, both of which were normal, and for further biochemical tests. The relevant urinary findings were a Grade I Sulkowitch reaction and an oxalate excretion in the range 90-110 mg. per day. The

* This patient died from renal failure three months after operation; terminally, he became oliguric and uraemic, and his urinary oxalate excretion decreased further.

blood estimations mentioned above, the urea clearance and urine amino-acids were found to be within normal limits. A further radiograph three months later showed a stone in the left renal pelvis, but she remained symptom-free for a year until she had another attack of renal pain, following which radiography showed that the calculus on the left side had disappeared. Occasional urinary oxalate estimations during the last year have shown results comparable with those quoted above.

Family 5. In this family there are two children only. The parents are not related, and they and other relatives tested do not show hyperoxaluria.

CASE 6. A girl, the first child, now aged 8 years, had painless haematuria at 2 and 3 years of age. At 5 years she had an episode of haematuria with abdominal pain and vomiting, and on radiography was seen to have bilateral renal stones and stones in the right ureter. On admission there were no abnormal physical signs and her blood pressure was normal. The urine was acid, free of cells and protein and sterile. The Sulkowitch reaction was Grade I and the amino-acids normal. Blood urea, total protein, sodium, potassium, chloride, CO_2 combining power, calcium, phosphorus and alkaline phosphatase were within normal limits. Radiographs of long bones were also normal.

Three calculi, consisting of calcium oxalate and a little phosphate, were removed from the lower end of the right ureter and she was discharged fit.

Re-investigation six months later was unhelpful, but at 6½ years she had a further attack of haematuria and the left renal stone was passed. Urine specimens tested for oxalate at this time showed increased values and she was accordingly readmitted at the age of 7 years for further investigations. There was little change in the renal opacities; bone marrow aspirate was normal and slit-lamp examination did not reveal any crystalline ocular deposits.

In addition to the tests mentioned above, the urea clearance, uric acid and serum protein electrophoresis were normal but the urine oxalate excretion averaged 170 mg. per day.

She has been followed for a period of one year and has remained well except for the passage of a stone and a mild attack of renal colic. The urinary oxalate excretion remains at its previous level.

CASE 7. A boy, the second child, now 6 years old, at 2 years developed retention of urine which was relieved by the removal of a stone from the urethra. He has since been symptom-free and was seen initially at 4 years of age, when there was no radiological evidence of nephrolithiasis.

He was admitted to hospital with his sister, and the same investigations were performed. All were normal except for the urinary oxalate excretion, which averaged 165 mg. a day.

Family 6. In this family there were four children and the parents are first cousins. The unaffected children, the parents and other relatives have normal oxalate excretions.

CASE 8. A boy, the first child, was first seen elsewhere at the age of 6 years because of nocturnal enuresis, frequency and polyuria of some duration. He had recently been rather lethargic. Physical examination and urine tests were negative, but a radiograph showed bilateral abdominal shadows thought to be calcified glands. He was then lost sight of until four years later when he was admitted to hospital with acute retention. He had had one previous such episode three years previously and the frequency and nocturnal enuresis had persisted.

He was undersized but otherwise appeared normal. His blood pressure was 120/80 and his blood urea 84 mg./100 ml. Shortly after admission he passed a stone and some gravel which were found to consist of calcium oxalate. As radiography showed bilateral renal stones he was transferred to Liverpool. Urine examination was normal but his blood pressure had risen to 130/100 and his blood urea to 110 mg./100 ml. Total serum protein and CO_2 combining power were slightly low, but serum chloride, calcium and alkaline phosphatase were normal. The phosphorus figure was a little high. A radiograph showed multiple bilateral and renal calculi with small kidney shadows, a right ureteric and two vesical calculi. The long bone structure appeared normal. He was operated upon and several calculi were removed from the small right kidney. Estimation of urinary oxalate at this stage revealed a high excretion (212 mg. per day). The urine amino-acid pattern was normal.

A month later his blood pressure had risen to 150/100 and his blood urea to 250 mg./100 ml. The vesical stones were removed at laparotomy but his subsequent course was one of slow deterioration with rising blood pressure and blood urea. Slit-lamp examination of the eyes was normal early in this terminal phase. During the fortnight before death his urine volume diminished and his urinary oxalate output fell to below 35 mg. per day. He died in uraemia 10 weeks after his transfer and autopsy was not permitted. Bone marrow aspirate taken after death contained no calcium oxalate crystals but post-mortem cerebrospinal fluid contained 0·42 mg. of oxalate per 100 ml.

Discussion

These are all classical cases of primary hyperoxaluria, except for Case 2 who has no urolithiasis although she is now almost 14 years old. The urinary oxalate excretion values are all between about 100 mg. per 24 hours and 400 mg. per 24 hours, and the individual values cannot be correlated with the severity or the apparent age of onset of the urolithiasis. The urinary oxalate excretion decreases during the last weeks of life as the terminal uraemic illness progresses, and we think that this may be associated with a phase of rapid oxalate deposition in the kidneys with the accumulation of at least the major proportion of the extra-renal deposits. The absence of detectable oxalate deposits

in the kidneys of patients with primary hyperoxaluria several years before death and in scarred pyelonephritic areas of the kidneys of one patient at autopsy (Scowen, Stansfeld and Watts, 1959; and unpublished observations), as well as the apparently normal bone development, except possibly when there has been prolonged renal failure, in spite of the calcium oxalate deposits at the growing ends of the bones at autopsy, are in conformity with this suggestion. Direct evidence of oxalosis during life was not obtained by sternal marrow aspiration biopsy or by slit-lamp examination of the eyes. It may be that trephine-biopsy of a cancellous bone or biopsy of a small muscular artery would be more informative in this respect.

Oxalosis only occurs if renal failure is accompanied by an abnormally increased endogenous oxalate production. There is no satisfactory method for the measurement of the blood oxalate level (see for example Barrett, 1943), but the observation that detectable amounts of oxalate were present in the cerebrospinal fluid and pleural effusion of the case reported by Scowen, Stansfeld and Watts (1959) and in the cerebrospinal fluid in Case 8 suggests that the concentration of this anion may be raised in the body fluids generally in the terminal stage of the disease.

Except for evidence of renal failure, the elevated urinary oxalate excretion was the only abnormal pathological finding in all of these patients. The value of this relatively simple diagnostic procedure in differentiating primary hyperoxaluria from other causes of juvenile urolithiasis, which do not carry such a grave prognosis, merits emphasis: Case 4 was diagnosed by this means before he presented with the clinical manifestations of renal calculi. Cases 1 and 8 illustrate the inexorable course of the disease and the failure of surgical intervention to influence its uniformly bad prognosis. All of our patients who were investigated in the pre-uraemic stage of the disease had normal serum uric acid levels. This is of interest in view of Aponte and Fetter's (1954) suggestion that the hyperuricaemia, which they observed in three cases with renal impairment, indicated that the disease was in some way associated with an abnormality of purine metabolism.

Although there are no reported cases of primary hyperoxaluria in patients whose urinary oxalate excretion was measured immediately after birth, there are clinical and pathological grounds for suggesting that the underlying error in the disease may be present at that time. The multiple incidence of the disease within sibships (Families 4 and 5 of this report) in the absence of any abnormality in the parents or more remote relatives, and the occurrence of one consanguineous parentage in the total of eight families which have been studied in our laboratories (Archer *et al.*, 1958; Scowen, Watts and Hall, 1959) are compatible with the disease being due to the operation of a rare recessive character; the two sexes appear to be equally affected both in number and severity. However, Shepard, Krebs and Lee (1958) reported a family in which hyperoxaluria was present in two and possibly three successive generations, suggesting a dominant type of hereditary pattern. It may be that this apparently dominant type of inheritance resulted from the mating of a subject who was homozygous for the recessive gene with the corresponding heterozygous subject (cf. Garrod's (1908) explanation of the apparently rare dominant type of inheritance of alkaptonuria). If this were so, it is curious that the presumably homozygous parent does not show any evidence of stone formation. An alternative explanation is that there are two different metabolic lesions which cause excessive oxalate excretion and that each has its own pattern of inheritance. There is evidence that a metabolic error involving one of the pathways of glycine metabolism results in excessive endogenous oxalate production in cases of the type which we have described (Watts, Scowen and Crawhall, 1959).

Summary

The clinical features of eight cases of primary hyperoxaluria occurring in three families, in one of which the parents were first cousins, are reported and the literature dealing with similar cases is briefly reviewed.

Measurement of the urinary oxalate excretion, which is always raised, is essential to distinguish these patients from other cases of juvenile urolithiasis which do not carry such a grave prognosis.

The precise level of the urinary oxalate in individual cases cannot be correlated with the apparent age at which stone formation begins or with its rate of progression. A marked diminution in the urinary oxalate excretion characterizes the terminal uraemic phase of the disease which may or may not follow a period of chronic renal failure.

Microscopic examination of aspirated sternal bone marrow and slit-lamp examination of the eyes for evidence of oxalate deposits have not been helpful in assessing the prognosis of individual cases and have given no indication of the development of oxalosis (disseminated extra-renal oxalate deposits). It is suggested, on the basis of indirect evidence, that this occurs only late in the evolution of the disease.

There appears to be no way of preventing the formation of calculi and the management of these patients conforms to the surgical practice in other cases of recurrent urolithiasis, the cause for which cannot be removed.

Hyperuricaemia was not encountered in these cases.

The familial incidence of the disease is compatible with its being due to the operation of a rare recessive genetic character.

We are indebted to the following surgeons for allowing us to investigate patients who were under their care: Mr. P. P. Rickham (Families 4 and 6) and Miss I. Forshall (Family 5). We are also pleased to acknowledge the help which we have received from Mr. J. T. Ireland and Mr. L. Rawlings.

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BOOK REVIEWS

Les Myocardites Aiguës Primitives de l'Enfant et les Virus Coxsackie. By BERNARD GRENIER. (Pp. 148. Fr. fr. 1,200.) Paris: Masson et Cie. 1959.

This monograph presents a review of recent work on the aetiology of acute primary myocarditis.

In the first chapter the author discusses some of the clinical and pathological aspects of this form of acute interstitial myocarditis, frequently called Fiedler's myocarditis, together with a discussion on points of differential diagnosis. In the second chapter the author discusses the viral aetiology at some length. Two main groups of viruses are associated with myocardial involvement—acute infectious fevers, mumps, influenza, acute respiratory disease, rubella, hepatitis and certain other viruses, herpes, vaccinia and poliomyelitis. The main substance of the monograph is devoted to an analysis of the rapidly accumulating evidence on the causal role of Coxsackie virus in acute primary myocarditis. This review shows that since Gear and others in South Africa reported on two epidemics of acute myocarditis in the newborn from which Coxsackie virus was isolated similar reports have been received from many other areas of the world. There now seems little doubt that Coxsackie virus B, and in particular serological types B2, 3 and 4, play a definite role in the causation of this disease. Having worked with Dr. J. Enders, the author has recognized the need for careful laboratory investigations in research into conditions of this nature, and the monograph concludes with a useful summary of the material needed and tests to be undertaken in such investigations.

The monograph contains a lot of useful information in a compact volume of 148 pages. There is a comprehensive bibliography.

Maladies Héréditaires du Métabolisme chez l'Enfant. By M. Lamy, P. Royer and J. Frézal. (Pp. 259; 72 figs. Fr. fr. 3,600) Paris: Masson et Cie. 1959.

It is difficult to praise this book too highly. The three authors cover a field of medicine, our knowledge of which is in a stage of rapid advance. It is also a specialized and difficult field, comprising a number of somewhat rare or very rare diseases of which the aetiology in almost every instance is quite different. The chapter headings are formidable. They leave the reader in no doubt that there is no manual for the doctor looking for a guide to children's diseases in everyday practice. A chapter on principles of genetics and the metabolic disorders is followed by those on conditions long recognized as disorders of internal metabolism and by others on conditions such as congenital hyperplasia of the adrenals less obviously included in the title.

The writing is admirably clear, concise and understandable. The language barrier need hardly cause any difficulty to anyone with the most elementary French vocabulary, such is the ability of the authors to make their subjects seem almost simple and to express their meanings in sentences which should be an example to writers in English.

Each subject is broken up into sections which fully cover the clinical, pathological and genetic aspects. There are many illustrations, histological, radiological and clinical of reasonably good quality.

It is refreshing to find, too, that either because of European interest in this field, or because the authors have taken the trouble to read the European literature, the references they give are very largely from this side of the Atlantic. Each chapter is very fully documented.

It is to be hoped that Professor Lamy's book will find its way into most paediatric libraries.

La Coqueluche. Séminaire organisé par le Centre International de l'Enfance. (Pp. 232; illustrated; Fr. fr. 1,400) Paris: Masson et Cie.

The International Children's Centre is to be commended for providing us with such a rich source of information on whooping cough. It is the report of an international seminar with representatives from 18 countries (although the participants were predominantly French), when the diagnostic, immunological and therapeutic aspects of pertussis were discussed. Much of the original work here reported has already seen the light of day in medical journals such as that of E. K. Anderson of Denmark and D. G. Evans of Great Britain, but there is a lot that is quite new. For the paediatrician and the specialist in infectious fevers the relatively small section on treatment should hold special interest. In spite of the many new treatments tried and the claims made for them, the cure for pertussis remains yet to be discovered. The clinical and laboratory research worker will find a great deal of current research work conveniently collected together in this volume. The lack of an index or a bibliographical list is to be regretted.

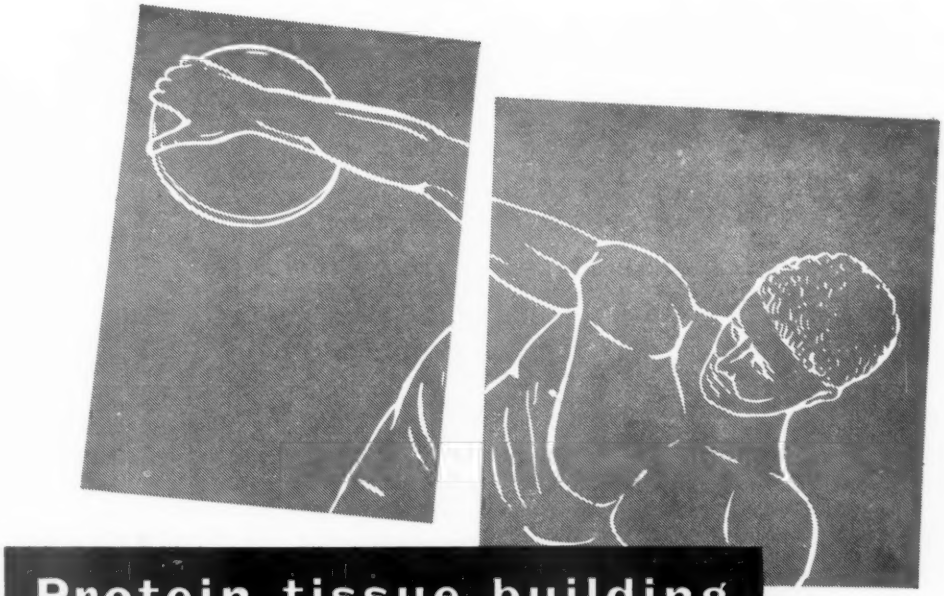
Healthier Babies—Happier Parents. By HENRY K. SILVER, C. HENRY KEMPE and RUTH S. KEMPE. (Pp. 244; illustrated. 8s. 6d.) London and Glasgow: Collins.

This book is so truly American that, though the publishers claim that it has been trimmed for the English market, nothing can disguise its origins. Equally divided into two parts, the first is a straightforward and comprehensive manual on child care which, it is claimed, 'can be read with profit before the baby arrives and should be regularly referred to thereafter': this claim is not idle. It could indeed profitably be read by nurses

up for the Children's Certificate Examination, and they would pass—easily. It is really remarkable how sensibly informative this section is. From line 1 'A baby does not look his best just after he is born—as everybody knows' to the last words in the book 'Happy second year and each succeeding one!', the pages turn with an easy swing; the mother is both informed and comforted through almost every possible eventuality. Throughout, the dominating note is one of quiet reassurance, and one is left with the impression that, provided the mother reads the book carefully and, of course, turns to her own doctor with any remaining doubts or difficulties, nothing can ever go wrong. Even tetanus 'is always a serious condition and total recovery may not occur for several weeks. However, once improvement has begun the eventual recovery is complete.' Information is given over a very wide field. There are 15 points to write down for a baby-sitter, the last of which being whether she will be taken home (though it does not say at what time!); it offers four different feeding schedules 'strict timetable', 'strict self-demand' and a 'modified self-demand', alternatively called 'flexible timetable'; there is a section on a dozen or more illnesses couched in straight medical textbook style, with signs, symptoms, complications and treatment; there is advice on making up the feed by two alternate techniques, standard cleaning technique or the terminal sterilization method; and there is this statement on breast and artificial feeding: 'Breast and bottle feeding are both perfectly satisfactory ways of feeding your baby. Although breast feeding is the natural way in which to feed a baby, the majority of babies in western countries are fed by bottle, and there is every reason to believe that both methods are equally successful in satisfying a baby's physical and psychological needs.' There it is, the simple truth put forward by two well-known Professors of Paediatrics and a specialist in the field of mental health and child guidance. It is probably true, although it is doubtful whether any paediatrician on this side of the Atlantic has ever said or even thought it with such simple conviction.

Section 2 is in the form of mothers' questions, 683 of them, designed to fill up any gap that may have been left in the mother's knowledge. Each question is answered carefully and sensibly, and one is left with a feeling of admiration for the endless patience exercised by American doctors in relation to their patients. What English mother would worry (in four questions) about her baby's shoes during the eighth month, and who, in this country, would be able to explain the intricate pros and cons of high uppers for a baby of this age. Then again, who would ask her paediatrician whether at 11 months her baby is capable of developing artistic tastes, to be told sensibly 'Yes, he is, in a rudimentary way' and 'the baby will enjoy pictures and music quite naturally if they are simple enough for him and therefore not boring'. A good example of the merits and also at times the tedious nature of the question and answer method is the following passage concerning overweight. Question 574: 'How much weight does a baby gain during the ninth month?'. Answer: 'Half an ounce a day or about a pound during the month.' Question 575: 'Should I be concerned if my baby seems overweight?' Answer: 'Usually not' with a further 12 lines of explanation. However, the mother persists—Question 576: 'Is baby likely to be healthier if he weighs more than the average?' Answer: 'No, not really' and four more lines of explanation. Question 577: 'Does a baby inherit his tendency to be overweight?' A guarded answer follows: 'A baby can inherit a tendency to gain weight easily, but this doesn't mean he has to be fat' and seven more lines of explanation. Still she persists—Question 578: 'Is it possible for a baby to become overweight even though he does not eat too much?' The answer is judicious, but one detects a tinge of exasperation: 'This depends on what you mean by "too much" . . . If a baby gets much overweight he is almost certainly eating too much.' Finally, Question 579: 'Should anything be done if my baby is overweight?' And the answer is worth quoting in full: 'Don't do anything without asking your own doctor. Usually a mild degree of plumpness in babies does absolutely no harm at all. Let your doctor decide whether your baby is too plump. If he feels your baby should lose weight he will give careful instructions about diet. Never put your baby on a special diet without asking your doctor. You might be leaving out foods which are important.' This quaint conversation is perhaps a little hard on the book since many of the sequences are intelligently planned to give valuable information on important subjects, but it does illustrate how these mothers, though copiously primed with detailed information on baby care and quasi-medical knowledge, lean on their family doctors and paediatricians, and how careful the authors are to encourage this attitude.

The illustrations, profusely scattered throughout the pages, are not more than thumbnail sketches of a pixy-like triteness, quite unworthy of the highly informative and serious tone of the book which really only lacks a little of the boisterous fun and self-confidence of Spock's paper-back, which sold for 5s. across the counter of chemists' shops and has since been translated into many languages including Russian. The present handsomely bound book, which could in this country undoubtedly be useful to the middle-class counterparts of the American mother, will surely not appear in Russian or English chemists' shops except perhaps in Bond Street.



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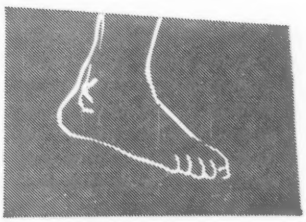

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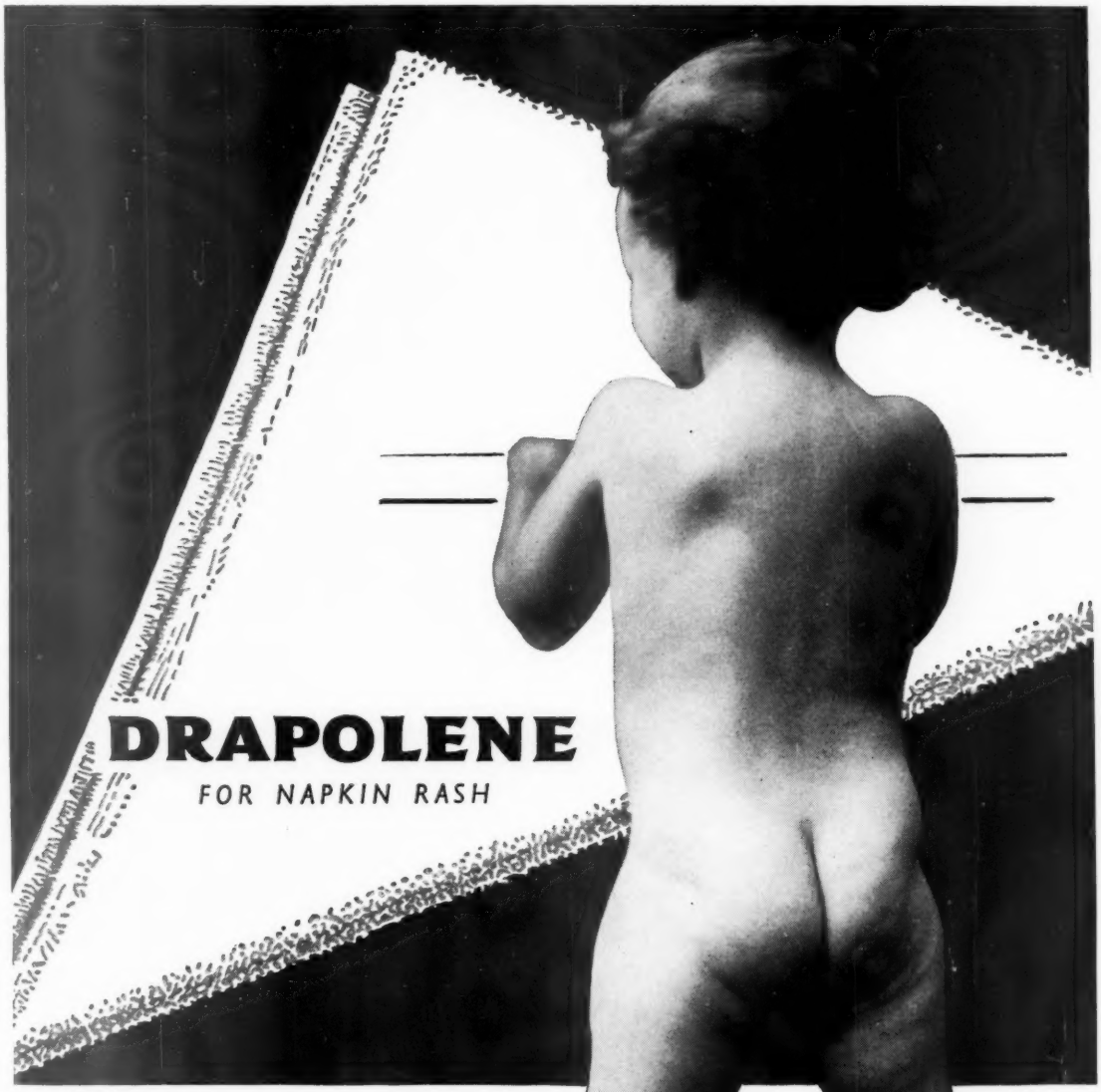

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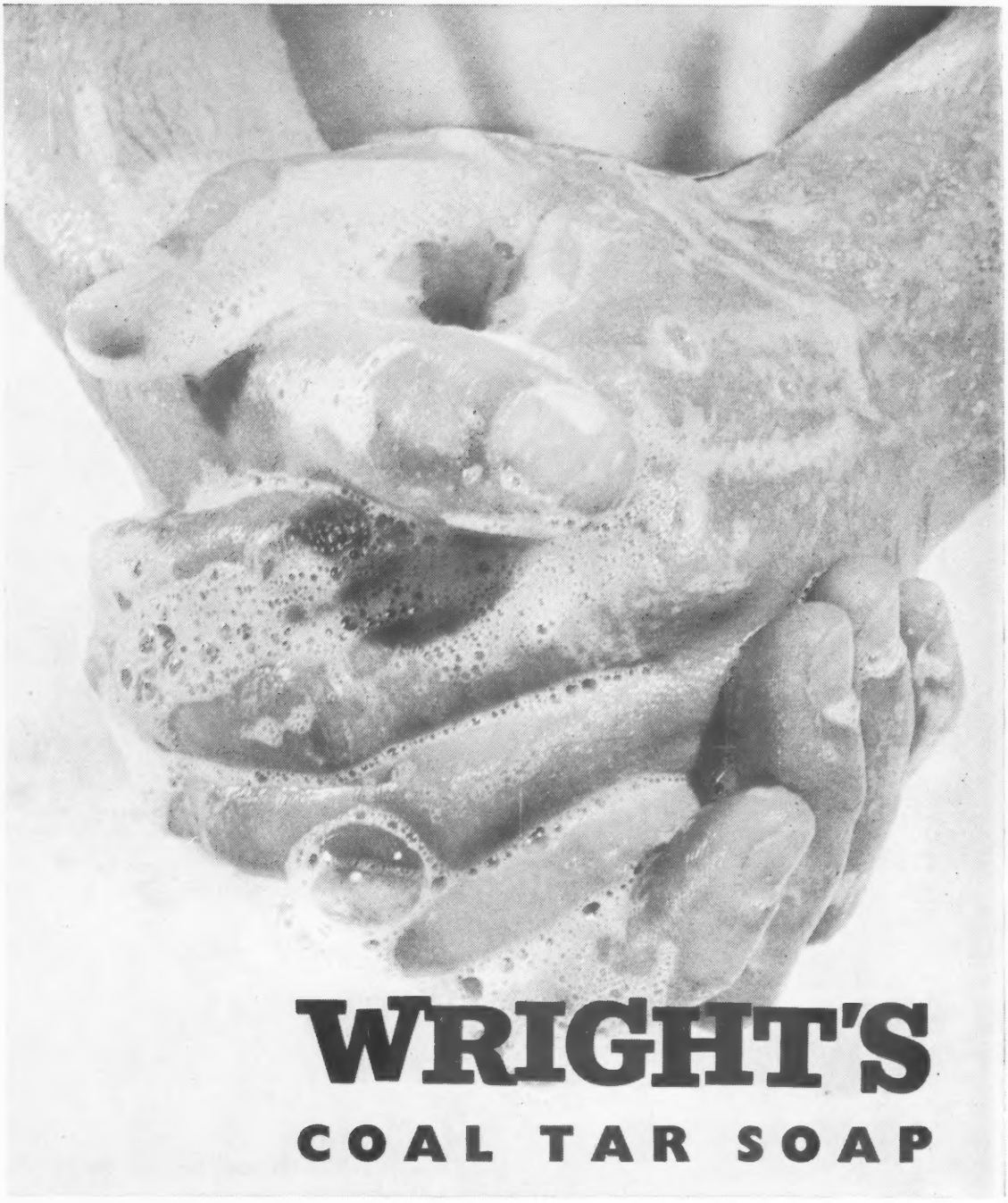

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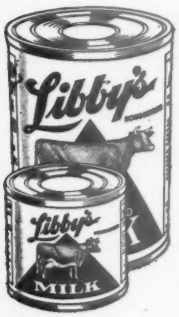

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